G.15

# WIRELESS ENGINEER

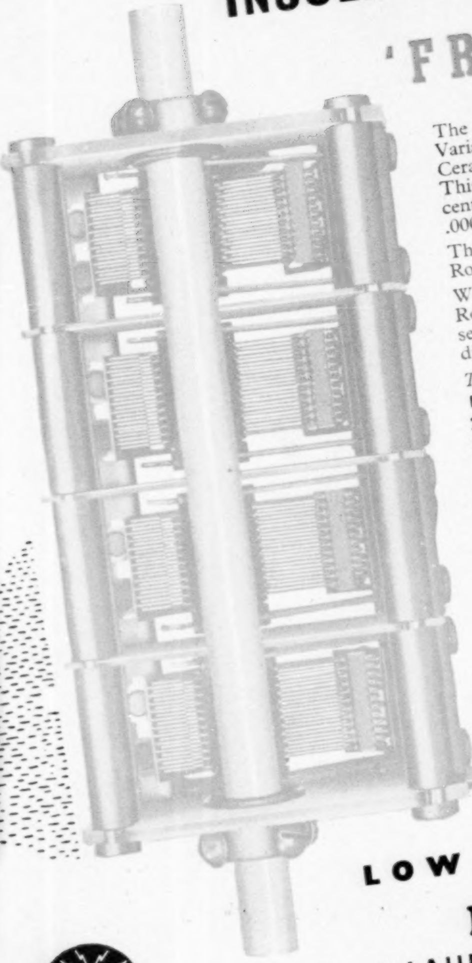
THE JOURNAL OF RADIO RESEARCH & PROGRESS

SEPTEMBER 1951

VOL. XXVIII No. 336 THREE SHILLINGS AND SIXPENCE

# FOR HIGH-FREQUENCY INSULATION—specify

# 'FREQUELEX'



The illustration shows a Four Gang Radio Variable Condenser using our "**FREQUELEX**" Ceramic Rod for the Centre Rotating Spindle. This Rod is 7½" long × .437" diameter, centreless ground to within plus or minus .0005". Maximum camber allowance of .002".

This is only one of many applications where Rods made to close limits are required.

We specialise in the manufacture of Ceramic Rods and Tubes of various sections in several classes of materials over wide dimensional ranges.

*The Principal Materials Are :—*

**1. Porcelain for general insulation.**
**2. Frequelex for High Frequency insulation.**
**3. Permalex and Templex for Capacitors.**

The degree of accuracy depends on the size of the Rod or Tube, but the standard degree of accuracy is outlined in the Inter Service Component Manufacturer's Council—Panel R Specification embodied in our Catalogue of Radio Frequency Ceramics, copy of which will be sent on request.

Large Rods up to 44" long and 1¼" square are used as supports for Tuning Coils, etc.

*We shall be pleased to have your enquiries for all sizes of Tubes and Rods. Prompt deliveries can be given for most sizes.*

*Condenser manufactured by Messrs.* WINGROVE & ROGERS LTD.

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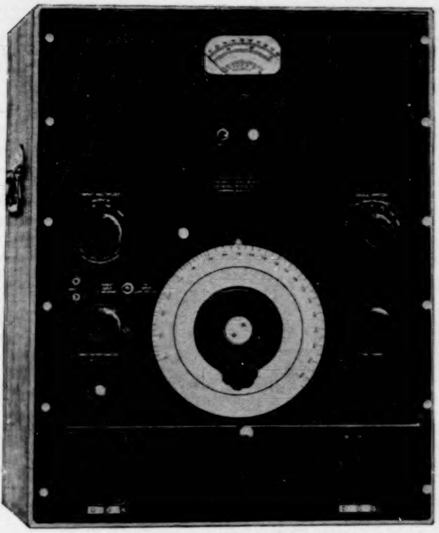

# INPUT VOLTAGE RANGE 1,000,000-1

**THIS analyser offers the simplest, most accurate and most direct method of measuring the amplitude and frequency of the components of any complex electrical waveform.**

**In its essentials it consists of a heterodyne-type vacuum-tube voltmeter with a highly selective i-f filter using three quartz bars. At only 60 cycles from resonance the attenuation is down by 75 decibels, yet tuning is very easy by virtue of the 4-cycle flat-top characteristic at resonance. Standards for both voltage and frequency are built into the analyser and can be used to check its calibration at any time.**

**The Type 736-A Wave Analyser is ideally suited for hundreds of types of harmonic-distortion measurements on any type of audio apparatus, broadcast receivers and transmitters, telephone and public address systems, oscillators, amplifiers and other vacuum-tube circuits; hum measurements on a-c operated communications equipment; harmonic-induction studies on telephone lines.**

## SPECIFICATIONS

**FREQUENCY RANGE:** 20 to 16,000 cycles.

**SELECTIVITY:** About 4 cycles flat-top band width. Response is down 15 db at 5 cycles, 30 db at 10 cycles, 60 db at 30 cycles from peak.

**VOLTAGE RANGE:** 300 microvolts to 300 volts full scale. Over-all range is divided into four major ranges, each of which is divided into seven scale ranges.

**VOLTAGE ACCURACY:** Within ± 5% on all ranges.

**HUM:** Suppressed by at least 75 db.

**INPUT IMPEDANCE:** 1 megohm for direct voltage measurements; 100,000 ohms with input potentiometer.

**ACCURACY OF FREQUENCY CALIBRATION:** ± (2% + 1 cycle)

**BUILT-IN CALIBRATORS:** For both voltage and frequency.

Write for complete data on this **WAVE ANALYSER** and **CATALOGUE L** covering a wide range of laboratory apparatus

CR 13

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**ELECTRICAL AND RADIO LABORATORY APPARATUS, ETC.**
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**TYPE D-197-A**

# IMPEDANCE BRIDGE

Direct Reading in R, C, L, D and Q • Operates from A.C. mains • Built-in 1000c/s oscillator and amplifier • Provision for external oscillator and galvanometer • Dual-sensitivity galvanometer key to facilitate final balance • Electronic earthing device to reduce zero errors and increase accuracy • Better than 1% accuracy over greater part of range.

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*Please send me Bulletin B-642 describing the Impedance Bridge advertised in "Wireless Engineer"*

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## RANGE OF MEASUREMENT

**RESISTANCE** 0.001 ohm to 1 megohm. **CAPACITANCE** 1 $\mu\mu$F to 100 $\mu$F.
**DISSIPATION (LOSS) FACTOR** 0-1.2. **INDUCTANCE** 1 $\mu$H to 1000 H.
**Q FACTOR** 0-60.

42b

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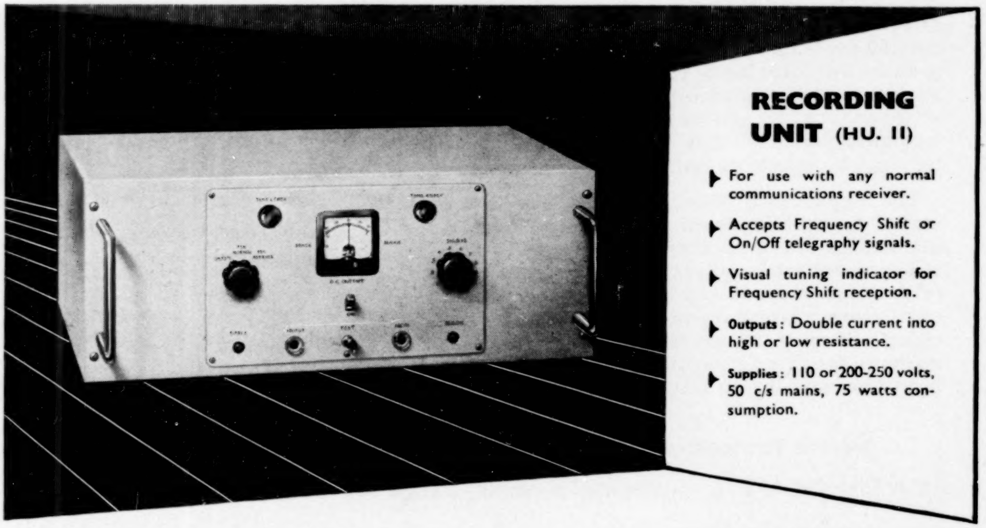

## RECORDING UNIT (HU. II)

- For use with any normal communications receiver.
- Accepts Frequency Shift or On/Off telegraphy signals.
- Visual tuning indicator for Frequency Shift reception.
- **Outputs**: Double current into high or low resistance.
- **Supplies**: 110 or 200-250 volts, 50 c/s mains, 75 watts consumption.

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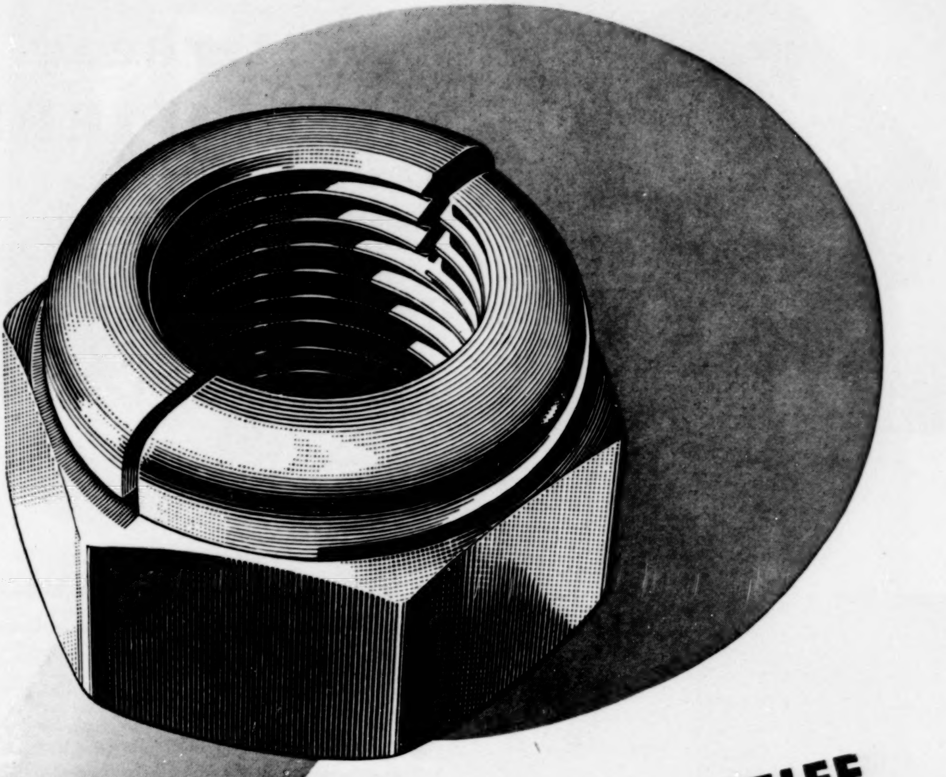

## *why call me a* STIFF *nut*

A Stiff Nut is a one piece nut which complies with R.A.E. Specification No. A.D.114 — a nut provided with means of increasing the friction between the thread of the nut and that of a standard bolt to an extent that the nut may be considered self-retaining. A Stiff Nut should be as light as is consistent with strength and be able to withstand all conditions of service use. It should be of a design which does not cause undue damage or excessive wear to the thread of the bolt on which it is mounted.

A perfect description, in fact, of the G.K.N. 'Aerotight' Nut — often casually referred to as a Lock Nut or Self-Locking Nut—which has the added advantages that it can be used over and over again without loss of efficiency. Its retentive properties are unaffected by oil, water or humidity.

**GKN 'AEROTIGHT' STIFF NUT**

*Supplied in Steel, Stainless Steel, Light Alloy, Brass and Bronze in Whitworth, B.A. and B.S.F. Threads. Recommended for all applications where vibration is encountered. Economical in use. No need for drilled holes, cotter pins, lock washers, etc.*

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Screw Division : Box 24, Heath Street, Birmingham 18

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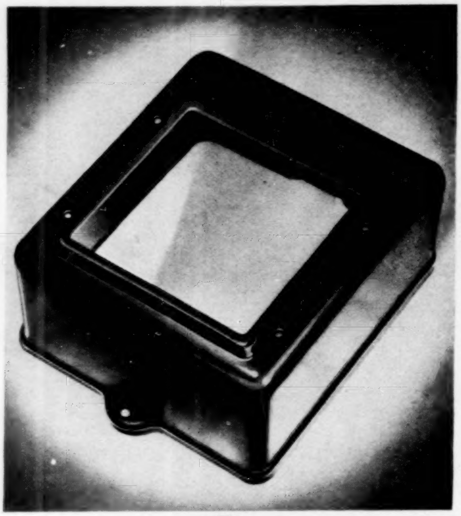

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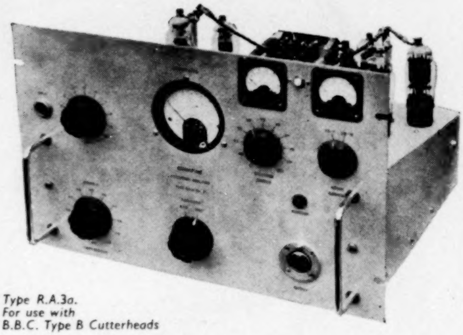
**Feedback Cutterhead AMPLIFIERS**



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*For use with*
*B.B.C. Type B Cutterheads*

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- **TRANSIENT RESPONSE**—Controlled feedback gives amazing response at very high audio frequencies.
- **WIDE RECORDING MARGIN**—High power amplifier allows wide margin between normal levels and extreme peaks.
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- **STABILITY**—Careful design avoids possibility of instability.

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*By D. V. Geppert, General Electric Co.,*
*Syracuse, New York*
350 *pages* 9 × 6 **42/6**

The aim of this book is to cover the physical characteristics, electrical characteristics, theory and mathematics of the eleven most basic types of electron tubes used in engineering.

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*By H. H. Skilling, Professor of Electrical Engineering and Head of the Department. Stanford University.*
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SPOTLIGHTGALVANOMETER
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## SPOTLIGHT GALVANOMETERS

### type GVM

*available in 5 designs:*

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| *TYPE GVM22:* | universal design:<br>1 to 100 mV, full scale.<br>5 to 500 $\mu$A, full scale. |
| *TYPE GVM23:* | direct reading in current, 2 to 500 $\mu$A, full scale. |
| *TYPE GVM11:* | uncalibrated, voltage sensitive. |
| *TYPE GVM13:* | uncalibrated, current sensitive. |

- ★ Excellent stability against vibrations.
- ★ Clamping device of novel design.
- ★ Lamp readily accessible from outside for adjustment or removal.

For further details, write for Bulletin 12101B.

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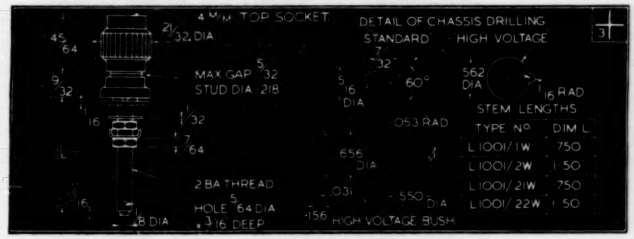
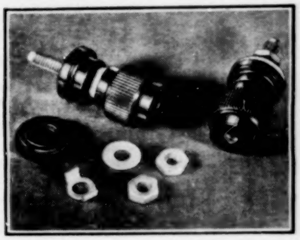
# The "Belling-Lee" page for Engineers


4 M/M TOP SOCKET
21/32 DIA
45/64
9/32
MAX GAP 5/32
STUD DIA ·218
1/16
1/32
7/64
L
2 BA THREAD
HOLE 5/64 DIA
3/16 DEEP
1/16
1/8 DIA
DETAIL OF CHASSIS DRILLING
STANDARD
HIGH VOLTAGE
7/32
5/16 DIA
60°
·562 DIA
1/16 RAD
·053 RAD
·656 DIA
·031
·550 DIA
·156
HIGH VOLTAGE BUSH
3

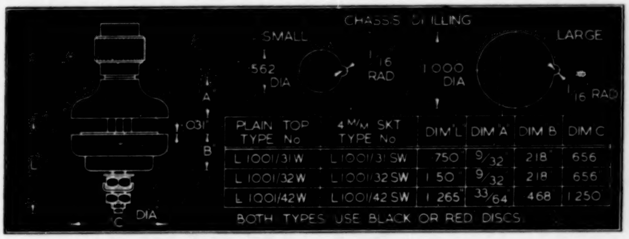
STEM LENGTHS

| TYPE Nº | DIM L |
|---|---|
| L 1001/1W | ·750 |
| L 1001/2W | 1·50 |
| L 1001/21W | ·750 |
| L 1001/22W | 1·50 |



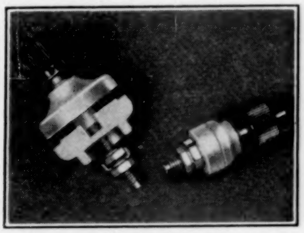
| Type | Rtg. in amperes | Peak Wkg. Voltage |
|---|---|---|
| "B" Standard | 15 | 1,000 |
| "B" High voltage | 15 | 2,000 |
| "H" | 100 | 1,500 |
| "F" | 30 | 1,000 |
| "L" Standard | 15 | 1,000 |
| "L" High voltage | 15 | 2,000 |
| "R" when fitted with insulating bush & washer | 9 | 350 |
| "W" | 15 | 750 |

The well-known "Belling-Lee" "B" type terminal is now offered as a *High leakage resistance* terminal (details below). Illustration above shows the standard and high voltage types, which can be supplied with plain red or black tops★ or with 4 mm. top socket, and have an anti-twist wedge on collar; no thread in clamping gap; special eared clamping washer and soldering spill for alternative methods of connection; nickel plated metal parts. Ratings and voltages of these and other terminals are shown in the table opposite.


CHASSIS DRILLING
SMALL
·562 DIA
1/16 RAD
1·000 DIA
LARGE
1/16 RAD
A
B
·031"
L
C DIA

| PLAIN TOP TYPE No | 4 M/M SKT TYPE No | DIM "L" | DIM "A" | DIM "B" | DIM "C" |
|---|---|---|---|---|---|
| L 1001/31W | L 1001/31 SW | ·750" | 9/32" | ·218" | ·656 |
| L 1001/32W | L 1001/32 SW | 1·50" | 9/32" | ·218" | ·656" |
| L 1001/42W | L 1001/42 SW | 1·265" | 33/64" | ·468" | 1·250 |

BOTH TYPES USE BLACK OR RED DISCS



## High Leakage Resistance Terminals

20 million of anything is a lot. 20 million megohms is the leakage resistance of the new "Belling-Lee" high leakage resistance terminal specially designed for instrumentation in nuclear physics, triode electrometers, high resistance bridges, etc. The smaller type has a resistance of 3·6 million megohms. Tests were taken at 850 volts, D.C. 55° F. and 70% relative humidity.

***Peak working voltage:—large type 5000 v. small type 2500 v.***

**20 Million Megohms**

★ *Supplied with standard letterings in quantities subject to a special quotation.*

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**TWIN CONE AXIOM 150**

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This 12-in. high fidelity unit has a twin-curvilinear diaphragm (patent No. 451754). A carefully designed magnet assembly using anisotropic material provides a total flux of 158,000 maxwells on a 1¾ in. pole. The back centring device is a dustproof bakelised linen disc with concentric corrugations.

The combination of these features gives this precision-built instrument an outstandingly wide coverage from 40 to 15,000 c.p.s. free from bass modulation effects.

An ideal fidelity reproducer for the record enthusiast and the connoisseur of wide range musical reproduction, it gives exceptionally fine transient and frequency response.

Frequency Coverage, 40/15,000 c.p.s.
Overall Diameter, 12-5/16in. (31.3 cm.)
Overall Depth, 6-15/16 in. (17.6 cm.)
Fundamental Resonance, 55 c.p.s.
Voice Coil Diameter, 1¾ in. (4.4 cm.)
Voice Coil Impedance 15 ohms at 400 c.p.s.
Maximum Power Capacity, 15 watts Peak A.C.
Flux Density, 14,000 gauss.
Nett Weight, 12 lb. 13 oz. (5.8 kg.).
Finish, Grey Rivelling Enamel.

For use with this model we recommend Goodmans High Fidelity Heavy Duty Output Transformer Type H.4. Nett Weight 5lb. (2·3 kg.)

A Bass Reflex Cabinet measuring approximately 30in. x 23in. x 16in., and a corner cabinet have been specially designed for this loudspeaker and working drawings are available.

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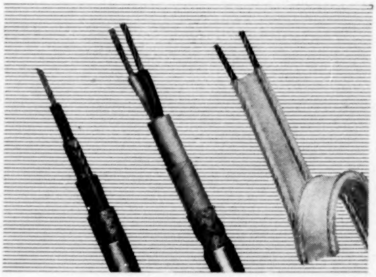
★ *The Basis of World Standards*

**TELCON R.F. CABLES**



Technical excellence supported by constant research and an unrivalled knowledge and experience of Radio Frequency Cable applications, ensures the continuance of the lead established by TELCON in this field.

Even before the introduction of Telcothene★ as a cable dielectric, an application pioneered by TELCON, a range of Radio Frequency cables with unique capacity and attenuation characteristics was produced, using Telconax.

Today, developments are still going on and the solution of any problems involving the application of Radio Frequency cables will be found in the wide range manufactured by TELCON

★ *Telcothene (Regd.)—Polythene processed by Telcon to provide specific characteristics*

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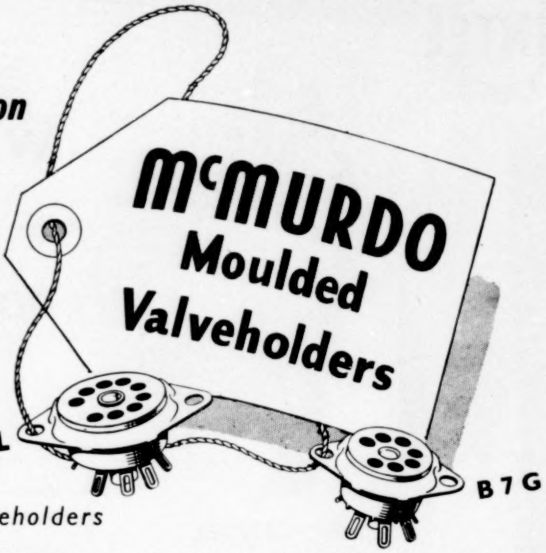

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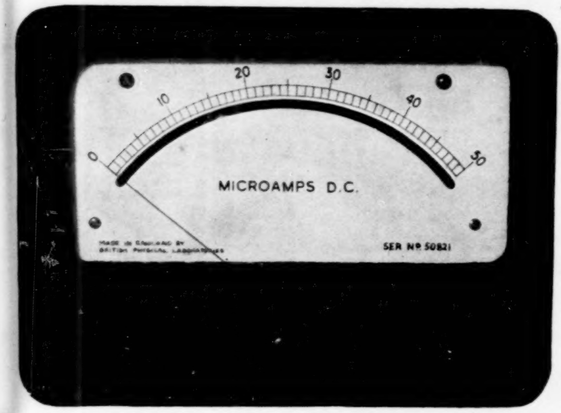

| SIZE | 2½″ | 3½″ | 5″ |
|---|---|---|---|
| RANGE | 25µA to 50A | 10µA to 50A | 10µA to 50A |

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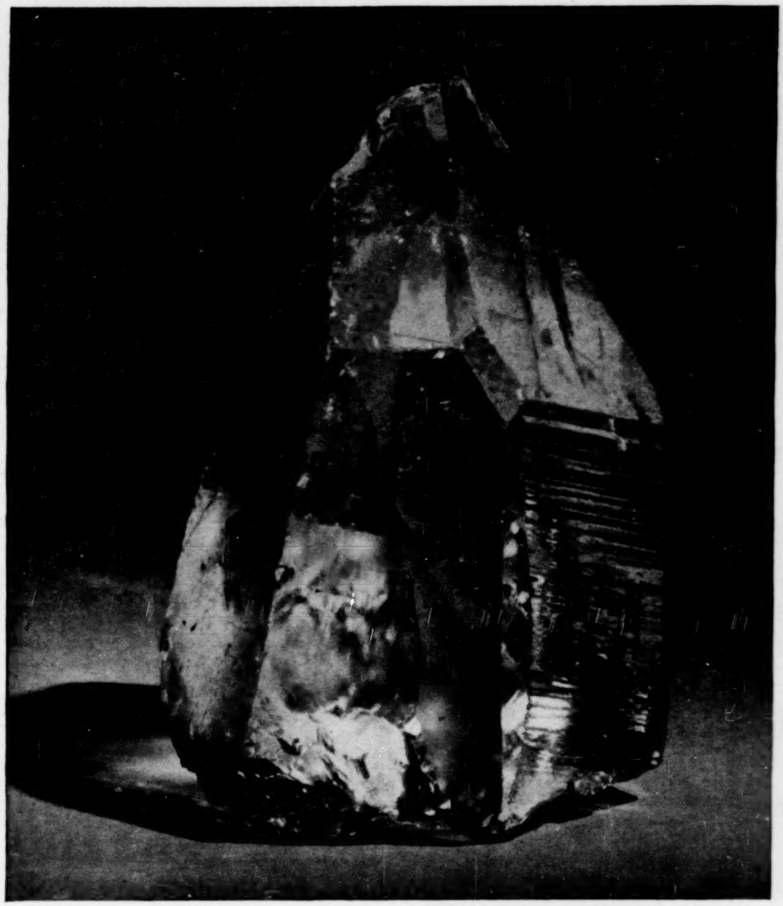

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CUT from only the finest raw quartz, ***Standard*** high grade crystal units are obtainable to accuracies better than 50 cycles in one megacycle. Artificially aged, gold plated and suspended in vacuo, these crystals greatly reduce drift under working conditions. They will maintain this high degree of accuracy ***under conditions of severe vibration*** and ***sharp changes in climatic conditions*** such as are encountered in mobile communication equipment.

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Models are available up to 100 kc at power outputs of up to 5 watts.

These instruments are distinguished for their superb engineering and individual accuracy.

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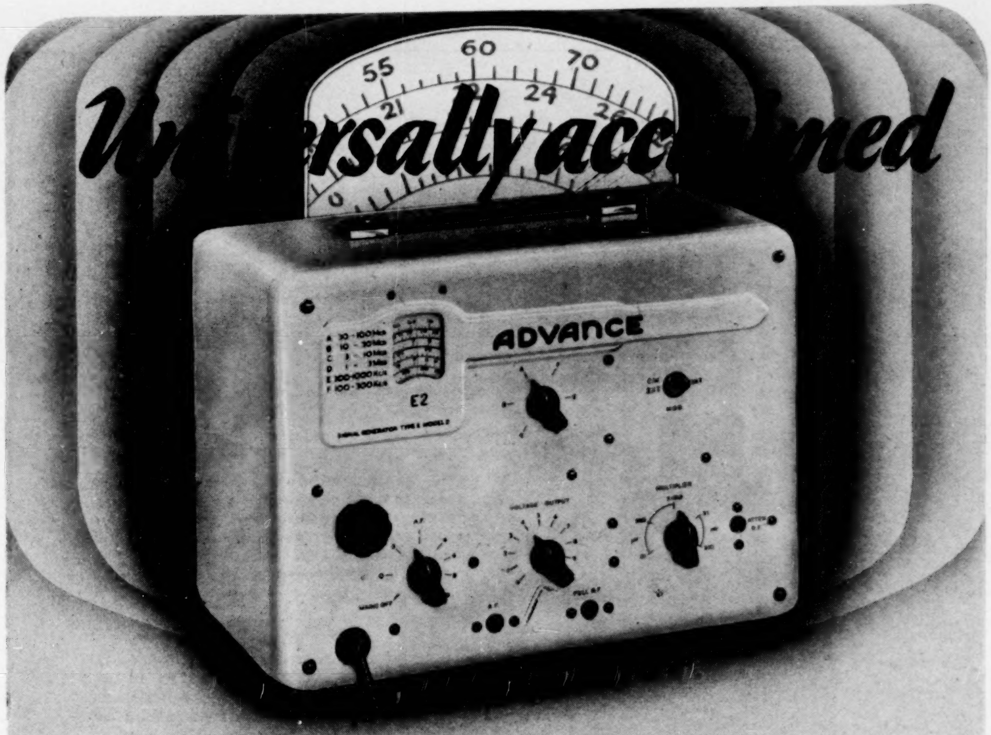

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**The Advance range covers 15 c/s - 310 Mc/s**

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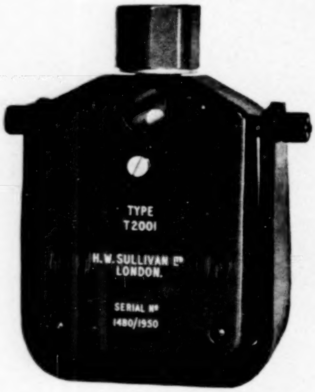

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# WIRELESS ENGINEER

**The Journal of Radio Research and Progress**

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## SEPTEMBER 1951

**Vol. XXVIII** **No. 336**

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**DATA ON THE MT57 TRIODE MERCURY VAPOUR RECTIFIER, ONE OF THE RANGE OF MULLARD THYRATRONS**

**LIMITING VALUES (ABSOLUTE RATINGS)**

| | | | |
|---|---|---|---|
| **Maximum Peak Anode Voltage** | | | |
| Inverse | | | 1000V * |
| Forward | | | 1000V |
| **Maximum Cathode Current. 25c/s and above.** | | | |
| Peak (for general control service) | | | 15A |
| Peak (for ignitor firing service) | | | 40A |
| Average (for general control service) | | | 2.5A |
| Average (for ignitor firing service) | | | 1.0A |
| Maximum averaging time | | | 15 secs. |
| Surge (maximum duration 0.1 secs.) | | | 200A |
| **Maximum Grid Voltage.** | | | |
| Before conduction | | | -500V |
| During conduction | | | -10V |
| **Maximum Grid Current.** | | | |
| Average (Averaging time 15 secs.) | | | 0.25A |
| Maximum Grid Resistor | | | 0.1MΩ |
| **Min. Cathode preheating time.** | | | 300 secs. |
| **Condensed Mercury Temperature Limits.** | | | 40 to 80°C |
| **CHARACTERISTICS.** | | | |
| Heater Voltage | | | 5.0V |
| Heater Current | | | 4.5A |
| Capacitance Anode-grid | | | 4μμF |
| Deionisation Time (approx.) | | | 1000μ secs. |
| Ionisation Time (approx.) | | | 10μ secs. |
| Anode Voltage Drop | | | 16V |
| **Control.** | | | |
| Anode Voltage | 60 | 100 | 1000V |
| Critical grid Voltage (approx.) | 0 | −1.75 | -6.5V |
| **Base 4-pin UX.** | | | |

* 1500V for condensed Mercury temperature up to 75°C

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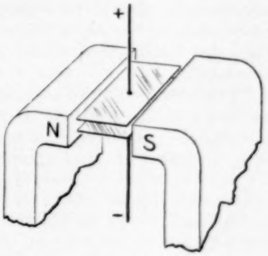
# WIRELESS ENGINEER

Vol. XXVIII SEPTEMBER 1951 No. 336

## Poynting's Theorem

IN our Editorial of February on "The Electromagnetic Momentum of Space" we referred to Poynting's theorem and confessed that we had doubts about its generalization; we concluded by saying that we considered its application to the case under consideration to be unjustified. In a book on electromagnetic waves recently published* a chapter is entitled "Poynting Vector and the Flow of Power." In it the author says "The interpretation of **E** × **H** as the power flow per unit area is an extremely useful concept . . . and although this interpretation never gives an answer which is known to be erroneous, it sometimes leads to a picture which the engineer is loath to accept. Most engineers find acceptable the concept of energy transmission through space, either with or without guiding conductors, when wave motion is present. However, for many engineers this picture becomes disturbing for transmission-line propagation in the d.c. case. When **E** and **H** are static fields produced by unrelated sources, the picture becomes even less credible. The classic illustration of a bar magnet, on which is placed an electric charge, is one which is often cited. In this example a static electric field is crossed with a steady magnetic field and a strict interpretation of Poynting's theorem seems to require a continuous circulation of energy around the magnet. This is a picture that the engineer generally is not willing to accept (although he usually does not question the theory of permanent magnetism, which requires a continuous circulation of electric currents within the magnet). Fortunately there exists an easy way out of the dilemma posed by this last example."

We do not propose to follow the author in his mathematical way out of the dilemma, because, more fortunately still, the dilemma does not exist. We disagree with the statement that the interpretation of **E** × **H** as the power flow never gives an answer which is known to be erroneous. In the figure we show two metal strips with an air space between them, maintained at a steady difference of potential, so that in the air space there is a vertical electric field. These strips are in the horizontal magnetic field of a magnet as shown. At every point in the space between the strips there is a definite product **E** × **H**, but to interpret this as a power flow along the space is obviously erroneous — perhaps ridiculous is a more appropriate word.



The trouble is due to a misinterpretation or unjustified generalization of the theorem. It is true that in his original paper† Poynting says, "Whenever there is both magnetic and electromotive intensity there is flow of energy," but the opening words of the paper are "A space containing electric currents," and a few lines further on he says, "Starting with Maxwell's theory, we are naturally led to consider the problem, how does the energy about an electric current pass from point to point?" There is no suggestion that the results can be applied to static conditions. The whole treatment is based on the Maxwell equations, the magnetic fields being produced by currents, either conduction or displacement; the electric and magnetic fields are associated with the displacement and movement of the same electric charges. Instead of saying that the existence of the product **E** × **H** indicates a flow of energy, it would be more correct to say that whenever there is a flow of energy, its magnitude is given by the product **E** × **H**. That was really Poynting's theorem.

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* "Electromagnetic Waves and Radiating Systems" by E. C. Jordan.

† *Phil. Trans.*, Vol. CLXXV, p. 343, 1884.

G. W. O. H.

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# Electromotive Force

THE term electromotive force has always been subjected to criticism on the grounds that it is not really a force but the integral of a force over a distance. In a recently published German textbook on the scientific foundations of electrotechnics the author states at the beginning that he will not use the term electromotive force for the above reason; he substitutes Urspannung (ur = original; spannung = tension or stress). In another recently published German textbook on electrotechnics the author says that he will use the customary term because other suggested names such as Urspannung have not been generally adopted. We understand that at a meeting of the International Electrotechnical Commission in Paris last year it was decided that 'magnetomotive force' should be replaced by another term not containing the word 'force,' and so it has been going on for many years and will probably continue to do so.

All this fuss is due to a narrow interpretation of the word 'force.' A standard dictionary tells us that force = strength, power, energy, etc. Nobody objects to the 'force' of circumstances simply because it cannot be measured in dynes. What is gained by substituting 'Spannung' for 'Kraft' in a German textbook? The dictionary gives Kraft = strength, vigour, power, force, energy, etc., while Spannung = tension, stress, strain, etc. Can anyone maintain that the latter terms are preferable to the former for expressing the root cause of the movement of electricity in a battery or dynamo? One may object that there is the danger of confusing electromotive force with electric force or field strength and magnetomotive force with magnetic force or field strength, but the words 'electromotive' and 'magnetomotive' indicate that the term 'force' is being used in the sense of the root cause of the electric and magnetic phenomena. The letters e.m.f. are too deeply rooted in the nomenclature and symbolism of electrical engineering to be brushed aside and replaced by others which are really no better as an expression of the conception involved. To anyone who still has qualms about the use of the word 'force' we would recommend the continued use of the symbols e.m.f. and m.m.f., but on the understanding that 'f' stands for '*fons et origo*'.

G. W. O. H.

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# National Radio Exhibition

THE 18th National Radio Show, which opened on 29th August, continues until Saturday, 8th September, and is open from 11 a.m. to 10 p.m. It is held this year at Earls Court, London, with the result that its usual title of Radiolympia is inapplicable; it seems strange to have a wireless exhibition in London which is not Radiolympia!

It is primarily an exhibition of broadcasting equipment among which television is prominent; 88 manufacturers and eight Government Departments are showing and there are exhibits designed to show the public some aspects of radio in operation. These include a television studio in action, radio-controlled model boats in a 30-ft tank, and an air attack on a model cruiser with control of naval fighter aircraft.

At the time of writing few details of the exhibits themselves are available, but it seems likely that the features of most technical interest are to be found in the television receivers. There is undoubtedly a tendency towards the use of large cathode-ray tubes and aluminized screens and ion traps are common. To economize in space, tubes with rectangular, instead of circular, screens are now made and there is a general tendency for screens to be flatter.

A general review of the more important technical developments and trends will appear in the October issue of *Wireless Engineer*.

# TELEVISION WAVEFORM DISPLAY

**By K. R. Sturley, Ph.D., M.I.E.E.**

*(Engineering Training Department, B.B.C. Engineering Division.)*

**SUMMARY.**—The construction of a simple display unit for the visual examination of the television waveform is here described. It uses the 50-c/s mains supply as a driver source, and selects any desired set of from 1 to 20 lines of both frames for separate and simultaneous display. With this simple apparatus there is a slow drift of the waveform due to automatic frequency correction of the nominal 50-c/s frame-synchronizing pulse at Alexandra Palace, but it can easily be corrected manually and is no serious disadvantage when the display is used for teaching purposes alone.

If a steady display is required the 50-c/s mains supply driver source must be replaced by 50 c/s derived from the frame-scan generator of the receiver. The additional equipment required is fully described and a photograph of the waveform on the c.r. tube screen is included. Since the two frames can be superimposed, the apparatus is very convenient for investigating defects in interlacing due to faulty frame-scan synchronizing at the receiver.

### Introduction

VISUAL examination of the transmitted waveform is of considerable importance to those concerned with operating a television transmitter. It can also be a valuable aid to the teacher of television principles and to the receiver designer, particularly when studying failure of interlacing due to inaccuracies of frame time-base synchronizing in the receiver. When training staff for the B.B.C.'s new television transmitting station at Sutton Coldfield the need to supplement a drawing of the television waveform by a display on the end of a cathode-ray tube was strongly felt. The starting of a Midlands television service provided the B.B.C. Training School at Evesham with a steady received signal and by means of quite simple apparatus it proved possible to display the waveform on the end of a c.r. tube.

The purpose of this article is to describe the construction of simple apparatus for selecting any given number of lines from 1 to 20 at any part of either frame. With this apparatus the displayed waveform is not absolutely stationary on the screen, but this disadvantage is not serious as far as teaching is concerned because correction for picture drift can be made manually. The apparatus, which is driven from the 50-c/s mains supply, may be modified to produce a stationary display by using the frame time base at the receiver as the driving source and the additional equipment required to do this is also fully described.

Television-waveform display requires the generation of a square-topped, variable-width pulse, whose timing can be varied relative to the transmitted frame-synchronizing signal. The method to be described uses a sinusoidal generating signal, the phase of which can be varied over 360°. The pulse is derived by squaring and differentiating the variable-phase sinusoidal voltage. Other methods of generating the pulse are possible; for example, a multivibrator, or similar device* can be made to generate the required pulse shape, the start of which can be varied by controlling the amplitude (or equivalent amplitude) of a saw-tooth signal from the frame time base of the television receiver. The reason for selecting the particular method described was its simplicity, ease of control (there are no 'blind' spots on the timing or phase control) and of construction.

### Principle of Operation

If the vision signal of a television transmission is connected to the Y plates of a cathode-ray tube and a time base synchronously operating at half frame frequency (approximately 25 c/s) is applied to the X plates, the whole of the waveform will be depicted on the c.r. tube screen, but it will be so cramped (even with a large-diameter screen) that no detail will be visible. The time base must be operated at half frame frequency since each frame contains $202\frac{1}{2}$ lines and frame 2 is consequently displaced $\frac{1}{2}$-line with respect to frame 1; i.e., the line-synchronizing pulse of frame 2 comes in the centre of the line vision signal of frame 1. Some improvement can be realized if the length of the trace is expanded by increasing the horizontal time-base frequency to an integral multiple of the frame frequency and if another half-frame frequency (25 c/s) time-base is applied to one of the Y plates of the c.r. tube, the other Y plate carrying the vision signal. For example, if the horizontal time-base is operating at 150 c/s, each frame signal will occupy three horizontal traces, one below the other. A disadvantage of this method is that the amplitude of the vision signal must be restricted to prevent it from overlapping the signal trace above or below it; even when the trace is expanded in this manner much of the detail is still obscured.

A considerable increase in visible detail can be obtained if the horizontal time-base frequency is increased to about 1000 c/s (20 × frame frequency) and a square-topped pulse is applied to

MS accepted by the Editor, September 1950

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* Chance, B. and Others, "Waveforms," M.I.T. Radiation Laboratory Series. Chapters 5, 9 and 10.

the modulator grid of the cathode-ray tube to brighten the trace for $1000\,\mu$sec every 1/25 sec. If the time-base is synchronized to the frame frequency and the pulse is derived from the latter, we shall see on the cathode-ray screen approximately 10 lines of the television waveform. The particular lines that are viewed will be determined by the timing of the brightening pulse, and if this timing can be continuously varied over 1/25 sec, the whole of the two frames of a television waveform can be examined 10 lines at a time.

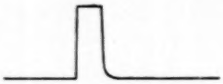


Fig. 1. *Shape of brightening pulse.*

Alternatively, and this is generally easier as well as advantageous, the recurrence frequency of the brightening pulse may be increased to 50 c/s and a 25-c/s saw-tooth time-base applied to one of the Y plates to separate the particular 10 lines of each frame. This means that there can be simultaneous observation of the corresponding 10 lines of each frame; furthermore, if the amplitude of the 25-c/s saw-tooth generator is variable, the two frame signals can be superimposed to check the efficiency of transmitter interlace by reducing this amplitude to zero.

The chief problem in designing television waveform-display apparatus lies in the production of the square-topped brightening pulse. This pulse should be constant in amplitude, with manual control of width and time position relative to the television frame frequency. Since the frame frequency of the B.B.C. television signal is nominally 50 c/s, and is locked to the 50-c/s mains, it seemed possible that the brightening pulse might be derived from the 50-c/s mains through a continuously variable phase-shifting device such as an iron-cored stator and rotor. The stator is arranged to give a rotating field when connected to the single-phase a.c. mains, and the position of the rotor relative to the stator is manually controlled. The output from the rotor can, therefore, be varied in phase continuously from 0 to 360° relatively to the 50-c/s mains input. The rotor output is amplified and applied to a valve, with zero bias and low anode voltage, which 'squares' the voltage wave above and below the centre line. This voltage is then differentiated through a RC network and applied to a valve operating in class C condition to remove the negative differentiated pulse. The positive pulse is amplified and finally 'squared' to produce the shape shown in Fig. 1; it is applied to the modulator terminals of a cathode-ray tube whose time base, operating at a convenient multiple of 50 c/s, is locked by the pulse. A 25-c/s saw-tooth time-base also locked to the pulse is connected to one of the Y plates of the c.r. tube and the vision signal to the other. A block schematic of the apparatus is shown in Fig. 2.

**Description of the Apparatus**

A complete circuit diagram of the apparatus, except the cathode-ray oscilloscope (indicated in block form), is shown in Fig. 3. The oscilloscope, a single-beam tube, has its own time base, a push-pull amplifier supplying both Y plates, and a 'modulator' input to its grid. The amplifier lead to one Y plate was disconnected and the output from the 25-c/s saw-tooth generator substituted.

The phase-shifting device is made from a "Ventaxia" fan motor, which originally had a shaded-pole stator and squirrel-cage rotor. The shorting turn surrounding each half of the four-field coils was removed and opposite pairs were joined in the series-aiding connection. The $20{,}000\,\Omega$ resistor $R_1$ and $0{\cdot}13\,\mu$F capacitor $C_1$ provide the required 90° phase shift to give the

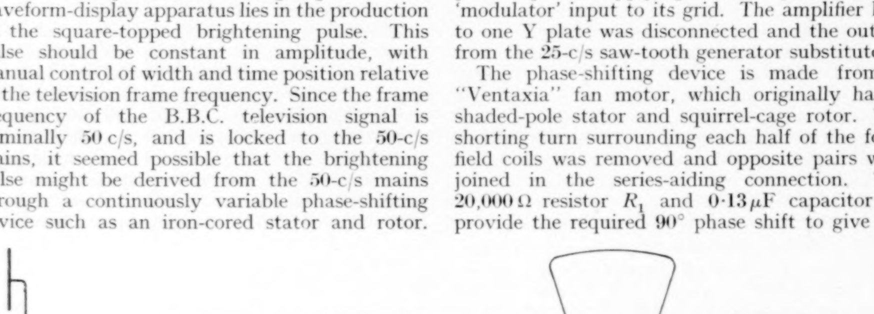

V.F OUTPUT
TELEVISION RECEIVER
CATHODE FOLLOWER
X
A2
A1
BRIGHTENING PULSE
G
K
SELF-RUNNING 25-c/s TIME-BASE
230V
A.C. MAINS
PHASE SHIFTER
SQUARER AND DIFFERENTIATOR
PULSE AMPLIFIER AND SQUARER
TRIGGERED 1,000-c/s TIME-BASE
SYNCHRONIZING →

Fig. 2. *Block schematic of television waveform display apparatus.*

two-phase supply to the stator. Capacitors $C_2$ ($0{\cdot}5\mu$F) and $C_3$ ($1\mu$F) are used to reduce harmonic currents in the stator and improve the waveform. It is not possible to tune both sets of field coils to 50 c/s because this upsets the phase-shift arrangements.

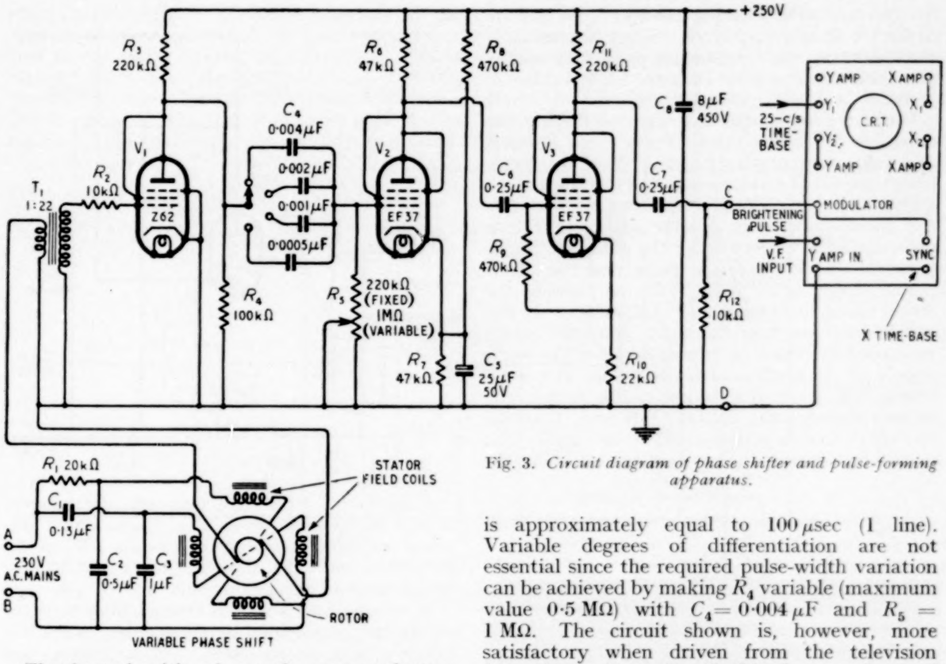

+250V
R3 220kΩ
R6 47kΩ
R8 470kΩ
R11 220kΩ
C8 8μF 450V
C4 0·004μF
0·002μF
0·001μF
0·0005μF
V1
V2
V3
Z62
EF37
EF37
T1 1:22
R2 10kΩ
C6 0·25μF
C7 0·25μF
R9 470kΩ
R4 100kΩ
R5
220kΩ (FIXED)
1MΩ (VARIABLE)
R7 47kΩ
C5 25μF 50V
R10 22kΩ
R12 10kΩ
C
D
BRIGHTENING PULSE
V.F. INPUT
25-c/s TIME-BASE
Y AMP
X AMP
Y1
X1
C.R.T.
Y2
X2
Y AMP
X AMP
MODULATOR
Y AMP IN
SYNC
X TIME-BASE
R1 20kΩ
C1 0·13μF
A
230V A.C. MAINS
B
C2 0·5μF
C3 1μF
STATOR FIELD COILS
ROTOR
VARIABLE PHASE SHIFT

Fig. 3. *Circuit diagram of phase shifter and pulse-forming apparatus.*

The short-circuiting rings and copper conductors were removed from the rotor and a total of approximately 250 turns of 28 s.w.g. copper wire (d.s.c.) was wound in the 17 rotor slots. Slots 1 and 2 were first filled, then 17 and 3, and so on to form a single coil, the two ends of which were taken to slip rings. The r.m.s. output voltage from the rotor is 0·60 V when the stator is connected to the 230-V 50-c/s mains. The rotor output voltage is applied to a reversed loudspeaker speech-coil transformer giving a voltage step-up of 1 to 22. Valve $V_1$, a high-slope pentode, with anode and screen strapped, squares the waveform. The resistance $R_4$ ensures a low anode voltage, and with $R_3$ forms the anode load of $V_1$. Variation of $R_4$ may be used to control the width of the output pulse from $V_3$; until the anode voltage falls below 10 there is no variation of pulse amplitude because valves $V_2$ and $V_3$ act as amplitude limiters. The square-wave output is connected to the grid of $V_2$ via the differentiating circuit $C_4$ $R_5$. $C_4$ is variable in four steps of two to one and the resistance $R_5$ is continuously variable over a range of five to one. When $C_4$ and $R_5$ are maximum the pulse width is about $2{,}000\mu$sec and embraces approximately 20 lines of the television waveform; at minimum setting of $C_4$ and $R_5$ the pulse width is approximately equal to $100\,\mu$sec (1 line). Variable degrees of differentiation are not essential since the required pulse-width variation can be achieved by making $R_4$ variable (maximum value $0{\cdot}5$ MΩ) with $C_4 = 0{\cdot}004\,\mu$F and $R_5 = 1$ MΩ. The circuit shown is, however, more satisfactory when driven from the television frame frequency as described in the second part of the article.

The valve $V_2$ acts as a class C amplifier and removes the negative pulse produced by differentiation. The output valve $V_3$ is grid self-biased and $R_{10}$ provides current negative feedback, which improves the pulse shape. Squaring the top of the pulse is obtained by having a low a.c./d.c. anode-load ratio. The output from $V_3$ is connected to the 'modulator' terminal of the c.r. oscilloscope, to the synchronizing terminal of the internal time base, and to the Y-plate amplifier input. The brightness of the trace is adjusted until the top and a little of the sides of the pulse are seen and the speed of the time base is set so that the top of the pulse is displayed at maximum length across the screen. The pulse is now disconnected from the Y amplifier and replaced by the v.f. signal output from a suitable point in the television receiver. To prevent loss of high-frequency content the signal should be taken from the receiver via a cathode-follower circuit. The lead from the receiver to the grid of the cathode follower should be as short as possible and it is preferable to have the valve as a probe. A suitable circuit intended for operating from the receiver v.f. amplifier stage is shown in Fig. 4.

The 25-c/s saw-tooth generator for separating the two frames is a simple gas-filled type and its circuit is shown in Fig. 5. Synchronization is obtained from the brightening pulse. Its output is connected via a potentiometer to one of the Y plates.

When the apparatus was used to display the television waveform two effects were noticed; one was a comparatively slow drift of the waveform backwards and forwards and the other was a slight 'shimmer'. The first appeared to be due to the Alexandra Palace Master Line and Frame pulse oscillator correcting for the phase variations between the 50-c/s frame pulse and the 50-c/s mains supply or to phase variation between the 50-c/s mains in London and at Evesham. It was at first assumed that the quick 'shimmer' might be caused by phase variations between the 50-c/s supply at Alexandra Palace and that at the receiver test point due to switching surges, etc. Closer investigation showed, however, that the c.r. tube time-base appeared to be causing the instability because the period between the synchronizing pulses was too long. The time base was changed from the self-running to the triggered type so that it only operated once after receiving the synchronizing pulse. The change to trigger action was accomplished by increasing the bias on the discharge valve to about 1 V greater than the value needed to prevent its discharging. Application of the brightening pulse to the synchronizing terminal initiated the discharge, which was followed by charge at a rate determined by the time constant CR of the charge circuit. With this modification the television waveform 'shimmer' had practically disappeared; the slow drift only was left, and this could be almost cancelled by suitable operation of the manual control of the 50-c/s phase shifter. The brightening pulse was inserted via a 5-pF capacitor into the receiver at the point from which the vision signal was taken and this indicated by a white line on the receiver screen the time instant at which the waveform was being examined.

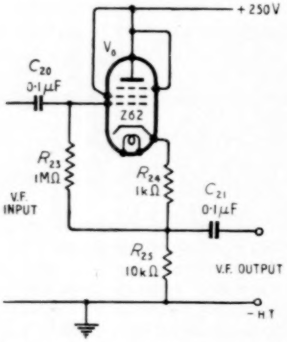
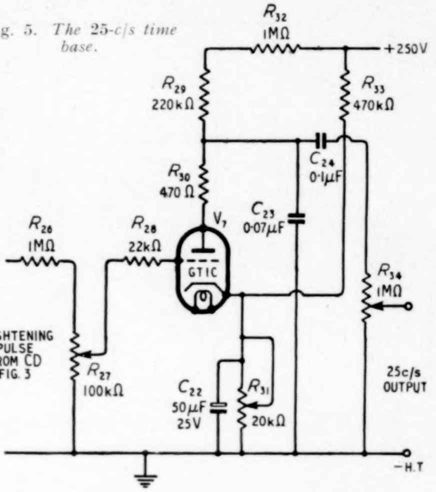


Fig. 4. *The cathode-follower v.f. circuit.*

Fig. 5. *The 25-c/s time base.*



It was realized that the slow oscillation of the waveform would not be satisfactory when the purpose was to monitor a transmission, and additional apparatus was constructed so that the 50-c/s mains input to the phase shifter could be replaced by a 50-c/s sinusoidal input derived from the frame-synchronizing pulse.

### Additional Apparatus for Frame Pulse Locking

A circuit diagram of the apparatus necessary to provide a 50-c/s sine wave from the frame pulse is shown in Fig. 6. It consists of an amplifier tuned to 50 c/s followed by a power output tetrode with another 50-c/s tuned-anode circuit supplying the phase shifter. The input voltage is taken from the receiver frame-scan generator output to the amplifier valve supplying current to the frame deflecting coils. The input, approximately sawtooth in shape, is integrated through the $R_{13}$ $C_9$ network before connection to the potentiometer control to valve $V_4$, a high-slope pentode. The anode of $V_4$ contains a circuit tuned to 50 c/s and it is coupled by another integrator circuit $R_{18}$ $C_{14}$ to the output power valve $V_5$. This has an anode circuit also tuned to 50 c/s across which is placed the phase shifter. Since the impedance at the phase-shifter terminals is a capacitive reactance (phase angle approximately 45°) it is necessary to cancel this reactance by an equivalent inductive reactance so that the impedance to the valve is resistive. This is achieved by including the inductance $L_3$; the resistive impedance presented to the valve is almost equal to half that of the resistance arm of the phase shifter; viz, 10,000 Ω. This is rather higher than the optimum load (7,000 Ω) required by the valve but under these conditions 150 V r.m.s. of 50 c/s is obtainable and this is adequate for producing the brightening pulse.

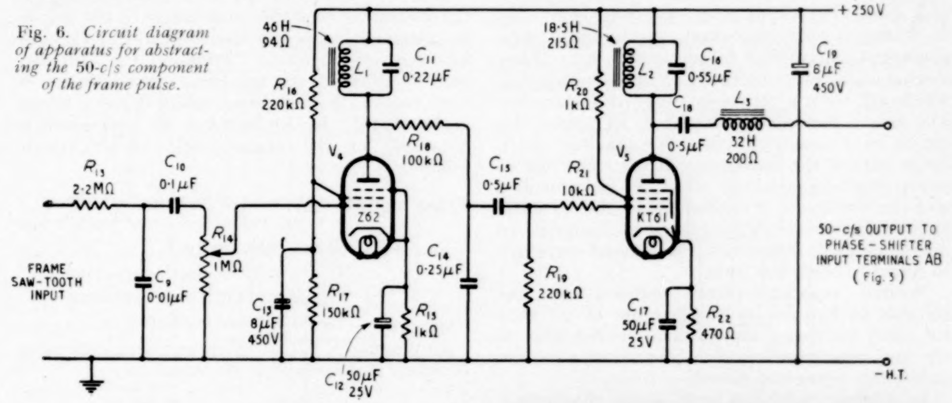

46 H
94 Ω
$L_1$
$C_{11}$
0·22μF
$R_{16}$
220kΩ
$R_{18}$
100kΩ
$V_4$
Z62
$R_{13}$
2·2MΩ
$C_{10}$
0·1μF
$R_{14}$
1MΩ
FRAME SAW-TOOTH INPUT
$C_9$
0·01μF
$C_{13}$
8μF
450V
$R_{17}$
150kΩ
$C_{12}$
50μF
25V
$R_{15}$
1kΩ
$C_{14}$
0·25μF
$C_{15}$
0·5μF
$R_{19}$
220kΩ
18·5H
215Ω
$L_2$
$C_{16}$
0·55μF
$R_{20}$
1kΩ
$C_{18}$
0·5μF
$L_3$
32H
200Ω
$R_{21}$
10kΩ
$V_5$
KT61
$C_{17}$
50μF
25V
$R_{22}$
470Ω
$C_{19}$
6μF
450V
+250V
−H.T.
50−c/s OUTPUT TO PHASE−SHIFTER INPUT TERMINALS AB (Fig. 3)

Fig. 6. *Circuit diagram of apparatus for abstracting the 50-c/s component of the frame pulse.*

The rest of the circuit after the phase shifter required no change.

An indication of the steadiness of the displayed waveform is shown by the photograph in Fig. 7 the exposure time for which was 4 sec. Frame 1 (the top) has moved its position slightly during the period of exposure due possibly to a noise impulse on the received signal; this slight shift would probably have passed unnoticed by the eye. The point selected for viewing the 10 lines of both frames is at the end of a frame thus showing that frame 1 ends at half line (the 202½ line) and frame 2 at the full line (line 405). The eight broad pulses forming the frame-synchronizing pulse and the subsequent lines of the frame-suppression period can be clearly seen. The tops of these pulses should be flat and the slight peak noticeable at the centre is due to a delayed reflection of the same pulse from a hill approximately 5 miles distant. The slight lift of the left-hand parts of the frame traces is due to a RC coupling between stages of the Y amplifier in the cathode-ray oscilloscope. The blob at the beginning of each line carrying vision signal is the post-sync 6-microsecond step for black-level clamping at the transmitter.

In order to check receiver interlacing it is only necessary to reduce the amplitude of the 25-c/s sawtooth voltage to zero so that the two frame signals are superimposed. Correct interlacing will show the line-synchronizing pulses of frame 1 centred between the line-synchronizing pulses of frame 2.

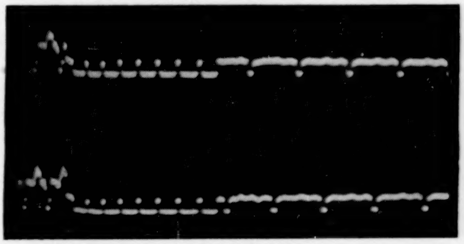


Fig. 7. *Photograph of ten lines of both frames of television signal (exposure 4 seconds).*

## Acknowledgment

The author wishes to acknowledge the assistance received from H. E. Kempson and E. Rizzoni in the construction of the apparatus.

# WIDE-RANGE VARIABLE-FREQUENCY OSCILLATOR

By A. Cormack, B.Sc.

*(Communication from the Staff of the Research Laboratories of The General Electric Company, Limited, Wembley, England)*

**SUMMARY.**—A phase-shift oscillator is described, which has been made to operate up to approximately 180 Mc/s. Bandwidths in excess of one octave can be obtained and the amplitude of oscillation remains substantially constant over most of the range. The frequency of oscillation is controlled electronically, thus making the oscillator very suitable for use as a swept oscillator.

## 1. Introduction

An oscillator whose frequency can be automatically swept over a given band has many very important applications; e.g., alignment of tuned r.f. amplifiers, etc. Many mechanically-swept oscillators have been designed which will cover a very wide range of frequencies. The usual method employed is to rotate, by means of a motor, a variable capacitor which forms part of the oscillatory circuit. The rate of sweep and bandwidth cannot easily be controlled and the amplitude of oscillation is liable to suffer large variation as the frequency is changed. To overcome these difficulties it was found necessary to resort to other methods.

Normal reactance-valve methods are not suitable to frequencies of the order of 100 Mc/s for really wideband applications. This is due to the low impedance which is inevitably reflected across the oscillatory circuit.

In a paper published by M. Ames (*Electronics*, May 1949) an electronically controlled phase-shift oscillator is described for which a frequency range of 16 Mc/s to 38 Mc/s is claimed. It consists of a phase-shift network and a single-stage RC-coupled amplifier connected in a ring. Provided the amplifier has sufficient gain, oscillation will occur at the frequency at which a phase change of 360° occurs around the whole ring. The phase-shift network consists of four cathode followers connected in cascade. The loads of these cathode followers are capacitive, and the phase shift at a given frequency is a function of the mutual conductance of the valves.

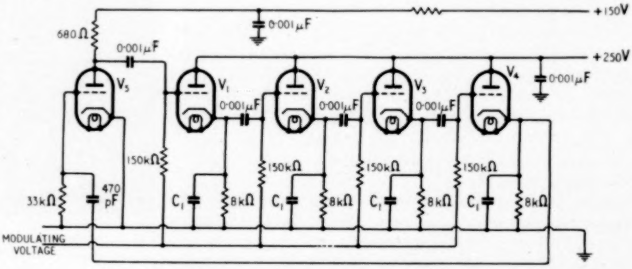


Fig. 1. *Basic circuit of oscillator comprising an amplifier stage and four cathode followers.*

This paper describes how this type of oscillator has been modified to cover a much wider frequency range and to operate at higher frequencies.

MS accepted by the Editor, August 1950

## 2. Oscillator Circuit

The basic oscillator circuit is shown in Fig. 1. Let us assume that the phase angle of the amplifier stage is always 180° and that all the cathode followers are identical. Provided the amplifier gain is sufficient, the condition for oscillation is that each cathode follower shall have a phase angle of 45°. In Appendix 1 an expression is obtained for the phase angle of a cathode follower.

$$\text{Phase angle} = \tan^{-1}\frac{\omega C_{gc}/R - \omega C g_m}{g_m^2 + g_m/R + \omega^2 C_{gc}(C + C_{gc})}$$

where $R$ = cathode load

$C$ = cathode-earth capacitance

$C_{gc}$ = grid-cathode capacitance

$g_m$ = mutual conductance

In practice $R \gg 1/\omega C$ and the above expression is shown in Appendix 1, to reduce to:—

$$\text{phase angle} \approx \tan^{-1}\frac{-\omega C g_m}{g_m^2 + \omega^2 C_{gc}(C + C_{gc})}$$

As the condition for oscillation is that the phase angle is 45°

$$\frac{\omega C g_m}{g_m^2 + \omega^2 C_{gc}(C + C_{gc})} \approx 1$$

$$\text{and } g_m \approx \frac{\omega C \pm \sqrt{\omega^2 C^2 - 4\omega^2 C_{gc}(C + C_{gc})}}{2}$$

Therefore an increase in $g_m$ will cause an increase in oscillator frequency. The maximum frequency will be determined in part by the maximum $g_m$. It will also be seen from the above expression for $g_m$ that given a certain $g_m$, the maximum frequency will be obtained when $C$ and $C_{gc}$ are a minimum. Now $C$ is made up of the cathode-earth capacitance plus the input capacitance of the following stage, which is a function of $C_{gc}$. Thus $g_m/C_{gc}$ may be considered as the criterion which determines the maximum frequency. The A1714 triode was chosen for the cathode followers as being the best valve available, having a mutual conductance of 9 mA/volt ($V_a = 150$ V, $I_a = 10$ mA), and grid-cathode capacitance slightly in excess of 3 pF. The same valve was also found most suitable in the amplifier stage.

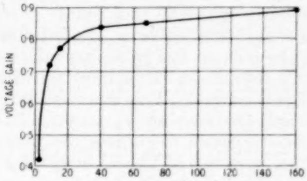


Fig. 2. *Variations of cathode-follower gain with frequency.*

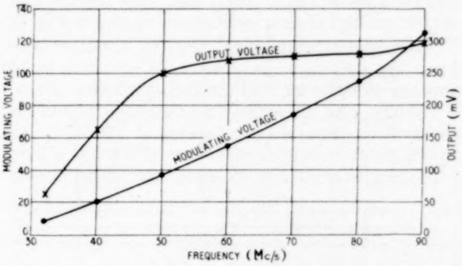


Fig. 3. *Variation of frequency with modulation and output with frequency.*

The gain of a cathode follower of fixed phase angle falls as $g_m$ is reduced. This is illustrated in Fig. 2, which was obtained by inserting typical circuit values in the formula for gain derived in Appendix 1. Now the frequency of oscillation is controlled by varying the mutual conductance of all four cathode followers and therefore as the frequency falls the attenuation through the cathode followers increases. Oscillation will cease when the attenuation through the phase-shift network is greater than the gain of the amplifier. The attenuation is a minimum when the phase angle of each cathode follower is the same and it is desirable that valves with similar mutual characteristics should be chosen.

With the basic oscillator circuit shown in Fig. 1, a frequency range of 32 Mc/s to 90 Mc/s was obtained. Capacitor $C_1$ consists only of strays, no other capacitor being present. A graph of modulating voltage plotted against frequency, and output voltage against frequency is shown in Fig. 3. The output voltage was measured across the load of a cathode follower output stage which was connected through a 4·7 pF capacitor to the cathode of the first phase-shift stage.

### 3. Phase Shift in the Amplifier

The assumption, made earlier, that the amplifier phase angle is always 180° is obviously inaccurate due to the effect of the output capacitance and due to transit-time effects. Let us now consider what the effect would be if the phase angle is greater than 180°, as it is in practice, at the higher frequencies.

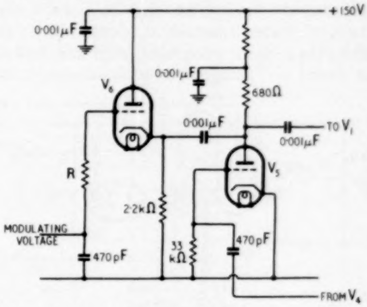


Fig. 4. *Cathode follower arranged to provide a variable load on the amplifier.*

The total phase change which must occur around the whole ring is 360°, and therefore if the amplifier phase angle is greater than 180° the phase angle of each cathode follower must fall below 45°. It was found in practice that the oscillator operated at 80 Mc/s when the mutual conductance of each cathode follower was approximately 8·5 mA/V. The other circuit constants, using the symbols as in Appendix 1, were $C = 10$ pF and $C_{gc} = 3$ pF. Substituting these values in the approximate formula for phase angle (Appendix 1) gives the angle to be 27½°. It also shows that if $g_m$ is fixed an increase in phase angle results in an increase in frequency.

Now the gain necessary to maintain oscillation is less at high frequencies than at low, due to the smaller attenuation of the phase-shift cathode followers as the frequency is increased. So it would appear that a reduction of the resistive load of the amplifier can be made at the higher frequencies. This would reduce the phase angle of the amplifier, increase the phase angle of the cathode followers, and an increase in frequency would result. However, as the gain obtainable at the lower frequencies with a lower amplifier load resistance is reduced also, the range of frequencies obtainable will be reduced.

The figures of Table 1 demonstrate the effect of varying the amplifier load.

**TABLE 1**

| *Amplifier Load* (ohms) | *Frequency Range* (Mc/s) |
|---|---|
| 680 | 32- 90 |
| 470 | 49-104 |
| 300 | 66-115 |
| 170 | 95-128 |
| 100 | 120-142 |
| 68 | 133-154 |

These results suggest that it should be possible to increase the frequency range of the oscillator appreciably by varying the amplifier load, at the same time as the four phase-shift stages are varied. It would obviously be most convenient if the amplifier load were electronically controlled so that it could be 'ganged' in some manner to the existing frequency control. Now the output impedance of a cathode follower is approximately a resistance of value $1/g_m$. Thus, we have a resistance whose value may be controlled by varying a voltage—the grid voltage of the cathode follower. The amplifier with its load shunted by the output impedance of a cathode follower $V_6$ is shown in Fig. 4. The introduction of a small resistor $R$ into the grid lead of $V_6$ produces an inductive component in the output impedance. The value of this resistance affects the oscillator output-voltage versus frequency characteristic and is chosen to make this as nearly level as possible.

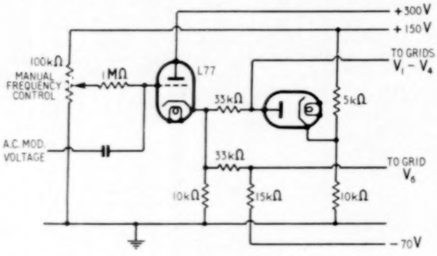


Fig. 5. *Frequency-control circuit.*

The best operation of the oscillator is not obtained if the amplifier load is controlled simultaneously with the phase-shift network. It has been found that valve $V_6$ should remain cut-off while the bias on the four phase-shift stages is raised to a maximum (as set by the dissipation limits of the valves). This bias should then be clamped and the bias on $V_6$ raised. The circuit which was employed to control the frequency in this manner is shown in Fig. 5. Provision is made for the insertion of an alternating sweep voltage and for manual control of the centre frequency.

A complete circuit, including an output stage, is illustrated in Fig. 6. Its modulating voltage and output voltage characteristics are shown in Fig. 7.

Now the circuit will oscillate satisfactorily when the amplifier load resistance is as low as 60 ohms and on the basis of the theory already given, a voltage gain of approximately two would be required to maintain oscillations at 150 Mc/s. In Appendix 2 a cathode follower, which has a load consisting of negative resistance and capacitance,

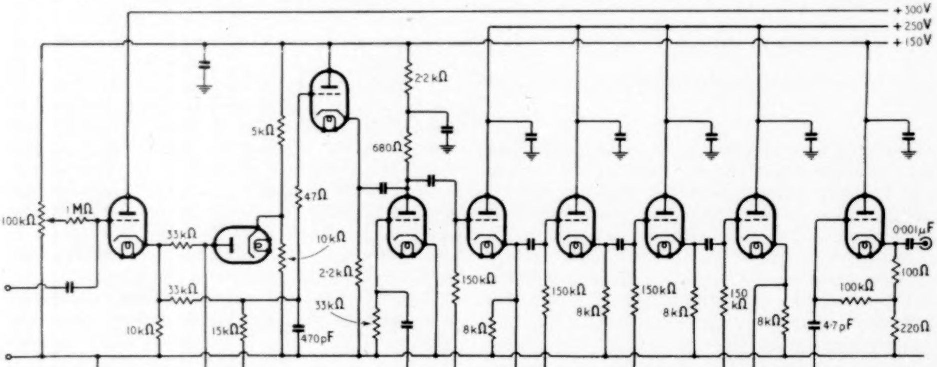


Fig. 6. *Circuit of complete oscillator including the frequency-control arrangements.*

is shown to have a negative-resistance component in its input impedance. Therefore, the gain of each cathode-follower stage will be higher than is calculated in Appendix 1. In fact, at 150 Mc/s the first three cathode followers in the oscillator phase-shift network actually provide a voltage gain in excess of unity, and the amplifier stage slightly less than unity. The accurate calculation of the gain per stage is exceedingly complicated and has been omitted from this paper.

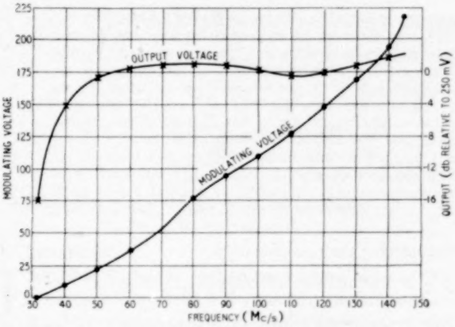


Fig. 7. *Performance curves of the oscillator of Fig. 6.*

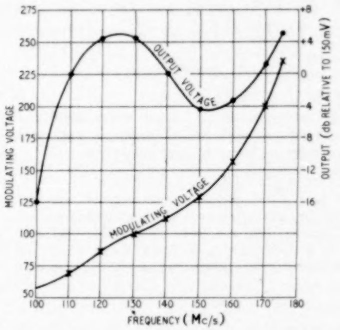


Fig. 8. *Performance curves of the oscillator of Fig. 6 with one cathode follower omitted.*

So far only oscillators employing four phase-shift cathode followers have been mentioned. If the number is reduced to three, the phase angle per stage is increased and, therefore, the frequency for a given value of mutual conductance is also increased. With a circuit containing three phase-shift stages, but otherwise identical with that in Fig. 6, a frequency range of 100 Mc/s to 170 Mc/s was obtained. Fig. 8 illustrates this oscillator's modulating voltage and output voltage characteristics. Further improvement was obtained by inserting chokes in the heater leads of the phase-shift stages. This reduced the cathode–earth capacitances and thereby increased the maximum attainable frequency. An oscillator incorporating this modification and employing three phase-shift stages reached 180 Mc/s and one with four, 170 Mc/s. However, the presence of these chokes caused instability below about 90 Mc/s. Frequencies slightly in excess of 190 Mc/s have been obtained at the expense of bandwidth, by reducing the fixed amplifier-load resistance.

It would appear that as the amplifier stage gain is less than unity, the stage is merely useful in that it causes a phase change of approximately 180°, and that it can be usefully replaced by another phase-shift network, say with further cathode followers. This may well be so, but no work has yet been carried out along these lines.

## Acknowledgments

This work has been carried out on behalf of the Ministry of Supply. The author wishes to thank the Chief Scientist, Ministry of Supply, for permission to publish this paper.

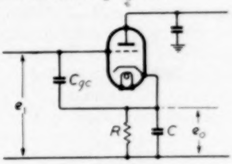


Fig. 9.

## APPENDIX 1

*Calculation of Gain and Phase Angle of a Cathode Follower*

Let $e_1$, $i_1$, and $i_a$ be instantaneous values of alternating voltage and currents respectively. Due to voltage $e_1$ applied to the grid, current $i_1$ flows through $C_{ge}$ and $e_1$ produces a current $i_a$ in the anode circuit.

Three circuit equations can be written down:—

$$\mu(e_1 - e_o) = i_a r_a + e_o \quad \ldots \quad (1)$$

$$e_o = \frac{(i_a + i_1)R}{1 + j\omega CR} \quad \ldots \quad (2)$$

$$i_1 = (e_1 - e_o)j\omega C_{ge} \quad \ldots \quad (3)$$

Substitute (3) in (2)

$$e_o(1 + j\omega CR) = Ri_a + R(e_1 - e_o)j\omega C_{ge}$$

$$\therefore i_a = \frac{e_o(1 + j\omega CR) - Rj\omega C_{ge}(e_1 - e_o)}{R}$$

Substitute in (1)

$$\mu(e_1 - e_o) = \frac{r_a}{R}\Big[e_o(1 + j\omega CR) - j\omega C_{ge}R(e_1 - e_o)\Big] + e_o$$

$$= \frac{r_a}{R}\left[e_o\{1 + j\omega R(C + C_{ge})\} - j\omega C_{ge}Re_1\right] + e_o$$

$$\therefore e_1(\mu + j\omega C_{ge}r_a) = e_o\frac{r_a}{R}\{1 + j\omega R(C + C_{ge})\} + e_o(\mu + 1)$$

$$\therefore \frac{e_o}{e_1} = \frac{\mu + j\omega C_{ge}r_a}{\mu + 1 + \frac{r_a}{R}\{1 + j\omega R(C + C_{ge})\}}$$

If $\mu \gg 1$ $$\frac{e_o}{e_1} = \frac{g_m + j\omega C_{gc}}{g_m + \frac{1}{R} + j\omega(C + C_{gc})}$$

$$= \frac{g_m^2 + \frac{g_m}{R} + \omega^2 C_{gc}(C + C_{gc})}{\left(g_m + \frac{1}{R}\right)^2 + \omega^2(C + C_{gc})^2}$$

$$+ j\,\frac{\omega C_{gc}\frac{1}{R} - \omega C_{gm}}{\left(g_m + \frac{1}{R}\right)^2 + \omega^2(C + C_{gc})^2}$$

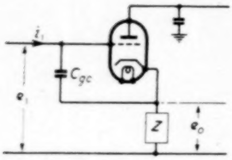


Fig. 10.

$$\text{Phase angle } \phi = \tan^{-1}\frac{\omega C_{gc}\frac{1}{R} - \omega C g_m}{g_m^2 + \frac{g_m}{R} + \omega^2 C_{gc}(C + C_{gc})}$$

If $R \gg 1/\omega C$, the equation

$$\frac{e_o}{e_1} = \frac{g_m + j\omega C_{gc}}{g_m + 1/R + j\omega(C + C_{gc})}$$

reduces to $\dfrac{e_o}{e_1} \approx \dfrac{g_m + j\omega C_{gc}}{g_m + j\omega(C + C_{gc})}$

Then $\tan\phi \approx \dfrac{-\omega C g_m}{g_m^2 + \omega^2 C_{gc}(C + C_{gc})}$ if $R \gg 1/\omega C$.

## APPENDIX 2

### *Input Impedance of a Cathode Follower*

Apply input voltage $e_1$ let output voltage which appears across $Z = e_o$.

Then input admittance $Y_{in} = i_1/e_1$ where $i_1$ is the current which flows through capacitor $C_{gc}$.

Equations (1), (2) and (3) of Appendix 1 apply if $R/(1 + j\omega CR) = Z$.

From (1) $i_a = \dfrac{\mu(e_1 - e_o) - e_o}{r_a}$

and (2) becomes $e_o/Z = i_a + i_1$

$$\therefore \frac{\mu(e_1 - e_o) - e_o}{r_a} = \frac{e_o - i_1 Z}{Z}$$

$$\therefore e_o = \frac{Z(\mu e_1 + r_a i_1)}{r_a + Z(\mu + 1)}$$

Substituting in (3)

$$\frac{i_1}{j\omega C_{gc}} = e_1 - Z\left[\frac{(\mu e_1 + r_a i_1)}{(r_a + Z(\mu + 1))}\right]$$

whence $Y_{in} = \dfrac{i_1}{e_1} = \dfrac{j\omega C_{gc}(Z + r_a)}{Z(\mu + 1) + r_a + j\omega C Z r_a}$

Let $Y = G + jB$

and let $\dfrac{1}{r_a} = g_a$

$$Y_{in} = \frac{j\omega C_{gc}(G + g_a + jB)}{G + g_a(\mu + 1) + j(B + \omega C)}$$

and if $\mu \gg 1$ then $g_a(\mu + 1) = g_m$

$$Y_{in} = \frac{[-\omega C_{gc}B + j\omega C_{gc}(G + g_a)]\,[G + g_m - j(B + \omega C_{gc})]}{(G + g_m)^2 + (B + \omega C_{gc})^2}$$

Considering the real part only

$$G_{in} = \frac{-\omega C_{gc}B g_m + \omega C_{gc} g_a B + \omega^2 C_{gc}^2 G + \omega^2 C_{gc}^2 g_a}{(G + g_m)^2 + (B + \omega C)^2}$$

Now let us work out the approximate value of $G_{in}$ for a single cathode-follower. As we are mainly interested in the input impedance at the high frequency end of the range let $\omega = 10^9$.

$$\left.\begin{aligned} G &= 2 \times 10^{-4} \\ C_{gc} &= 3 \times 10^{-12} \\ g_m &= 10^{-2} \\ g_a &= 2{\cdot}5 \times 10^{-4} \\ B &= 10^{+9} \times 10^{-11} \end{aligned}\right\} \quad G_{in} \approx -1 \times 10^{-3}$$

Now let us consider the input impedance to the same cathode follower when $G$ is negative and with $G \Rightarrow G_{in}$ (still considering the real part only).

Then new input $G = G_2$

$$= -1{\cdot}09 \times 10^{-3}.$$

Thus the input impedance of a cathode follower, which is itself feeding into an exactly similar cathode follower, contains a negative resistance term. Due to this, the gain of the first stage is effectively increased.

# TIME-DELAY MEASUREMENTS ON RADIO TRANSMISSIONS

## *Results on Medium Frequencies*

By R. Naismith, M.I.E.E., and E. N. Bramley, M.Sc.

*(Communication from the National Physical Laboratory)*

**SUMMARY.**—Measurements of the delay of the first ionospheric echo after the ground ray have been made over distances from zero up to 1,200 km on frequencies between 0·7 and 2·0 Mc/s. It is shown that there is some stratification in and below region E but the favoured delay times indicate an apparent height of reflection which decreases from 97 km to 90 km as the distance is increased up to the limit of the direct ray. It is also shown that there are three subsidiary reflecting regions at apparent heights of 120–130 km, 105–110 km and 70–76 km which are effective under certain conditions defined in the paper. Most of the work was done at a frequency of about 2 Mc/s, using the Loran type of radio navigational aid, and basic data are given which should be useful in the construction of 'sky-wave correction charts' for Loran use. The standard deviation of a single observation during night-time decreases from 22 microseconds to 10 microseconds as the distance of transmission increases from about 170 km to 1,200 km. The corresponding standard deviation of equivalent height increases from 4·5 km to 7·5 km over this range.

### 1. Introduction

FOR radio-wave transmissions by way of the ionosphere, there is a considerable amount of information on the virtual height of reflection at vertical incidence for different frequencies and at various times of the day and season. The need to use or avoid reflection from the ionosphere, particularly in the case of radio navigational aids has introduced a new interest in the height of reflection, especially as it affects oblique-incidence transmissions. The information in this paper relates to frequencies between 0·7 and 2·0 Mc/s and extends the vertical-incidence measurements to distances of 1,200 km, which is about the maximum distance at which the direct signal could be received. Most of the time-delay measurements were made on a frequency of 2·0 Mc/s with the Loran type of navigational-aid equipment which depends upon a comparison between the times of travel of the waves from the special Loran transmitters to the point of reception. Beyond the range of the direct wave the path of the signals is through the ionosphere, and the time of travel will be correspondingly increased: it will also vary with ionospheric conditions, and one of the objects of the work described in this paper is to assess the magnitudes of the errors which may arise from such variations. Basic data are also given to enable correction charts to be drawn for the use of Loran beyond the range of the direct ray. All the measurements were made with the midpoint of the transmission path within the latitude range 52°–61° N.

### 2. Theoretical Considerations

The experiments to be described are measurements of the delay time between the arrival of ground and sky waves at various distances and on different frequencies. For each measurement, the results can be interpreted as giving an equivalent height of reflection of the ionospheric wave, assuming both waves to be propagated with the velocity of light in free space, $c$, throughout these paths. This assumption is not strictly justified for the ground wave which is slightly retarded as a consequence of the finite conductivity of the earth. It may be shown, however, that for the frequencies and distances used, this effect is negligible, and the delay times may be converted to equivalent heights assuming the same velocity, $c$, for each path.

The experiments thus provide values of the equivalent height of reflection at different distances and frequencies, and it is of interest to consider the correspondence which may be expected from the various results. In particular, we can obtain a check on the validity of Martyn's theorem[1] on equivalent paths. It follows from this theorem that the same equivalent height of reflection will be obtained for transmissions at various angles of incidence, $i$, at the ionosphere, and frequencies, $f$, so long as $f \cos i$ remains constant. This strictly applies only to a medium with no horizontal ionization gradients above a flat earth, in the absence of a magnetic field. The curvature of the earth itself does not affect the validity of the result, and for reflections from region-E of the ionosphere, which are the subject of this study, it may be shown that the effect of the curvature of the ionosphere is also negligible at distances up to the maximum range used. Hence, if the portion of the ionosphere involved is uniformly stratified, we should expect Martyn's theorem in its simple form to be applicable to the results.

MS accepted by the Editor, August 1950

## 3. Description of Experiments

Measurements of the equivalent height of reflection have been made over a period of several years at the Radio Research Station, Slough, by the ordinary vertical-incidence sounding technique.

A further series of measurements was made, with the co-operation of the British Broadcasting Corporation, using certain high-power broadcast senders modified to emit pulses of suitable duration. The transmissions were received at Slough, where a ground-wave signal was available in each instance, so that the ionospheric delay times could be measured. Photographic records were taken, the requisite time-base synchronization with the emitted pulse being obtained via the grid system of the a.c. supply. The two stations involved, Washford and Moorside Edge, were respectively 196 and 255 km from Slough, and they both operated on the frequency of 0·877 Mc/s. Transmissions from Washford were also made on 0·668 Mc/s. Measurements on the Washford transmissions were made on 16 nights during August and September 1943 between 2330 and 0430 G.M.T., and again in November for six nights between midnight and 0300 G.M.T. During the November period measurements were made alternately on transmissions from Washford and Moorside Edge.

A third series of measurements was made on transmissions from various Standard Loran stations. These observations differ from those described above, in that an effort was made to equalize the amplitudes of the two received pulses involved in the delay measurements. The programme for this series was arranged to provide an estimate of the delay of the first echo and of the major echo relative to the ground-ray signal at varying distances. The trajectories and distances at which the observations were made are shown in Table 1, together with the period and number of observations made at each place. The transmissions from Hebrides, Iceland and Faroes were on a frequency of 1·95 Mc/s; those from Clee Hill, Danby and Port Errol were on 1·90 Mc/s. In this series over 25,000 observations were made, and it is considered that sufficient data have been obtained to justify the deductions concerning the statistical distribution of delay times and equivalent heights. There is no evidence of a marked seasonal dependence of these quantities, although a small variation of this nature could have been missed. When distances exceeded about 300 km it was necessary to make observations, as far as possible, over an all-sea path in order to obtain a sufficiently strong direct ray. This feature governed the choice of most of the sites used for the reception of the signals. Fig. 1 shows the relative position of the transmitters and receivers and illustrates this fact. For the extreme distances it was sometimes necessary to use a Beverage type of aerial.

TABLE 1.

| Stations | | Distance Apart (km) | Approx. Latitude of Midpoint (Degrees) | Observations | |
|---|---|---|---|---|---|
| Transmitter | Receiver | | | Period | Number |
| Clee Hill | Slough | 170 | 52 | 16th–21st September, 1944 | 1,540 |
| Danby | Slough | 332 | 53 | 16th–21st September, 1944 | 946 |
| Hebrides | Portrush | 332 | 57 | 20th–30th August, 1944 | 5,421 |
| Faroes | Thurso | 367 | 60 | 27th Nov.–8th Dec., 1943 | 2,265 |
| Port Errol | Wells | 522 | 55 | 16th–24th March, 1944 | 1,644 |
| Faroes | Portrush | 693 | 58 | 20th–30th August, 1944 | 3,744 |
| Hebrides | Treligga | 854 | 54 | 29th April–6th May, 1944 | 2,681 |
| Iceland | Thurso | 990 | 61 | 27th Nov.–8th Dec., 1943 | 1,148 |
| Faroes | Wells | 1,053 | 57 | 16th–24th March, 1944 | 2,726 |
| Iceland | Portrush | 1,147 | 60 | 20th–30th August, 1944 | 1,005 |
| Faroes | Treligga | 1,208 | 56 | 29th April–6th May, 1944 | 2,450 |

## 4. Results

### 4.1. *Vertical Incidence Measurements*

There exist many thousands of observations of the equivalent height of reflection from region E measured at vertical incidence at Slough, and we give in Table 2 the average, and extreme monthly mean noon and midnight values, over a period of seven years (1943–49) for summer and winter (June and December) conditions. The day values

TABLE 2.

| | June | | December | |
|---|---|---|---|---|
| | Noon | Midnight | Noon | Midnight |
| Maximum | 110 km | 121 km | 130 km | 117 km |
| Minimum | 100 km | 110 km | 115 km | 110 km |
| Average | 106 km | 118 km | 121 km | 113 km |

refer to normal region E, while those for night-time refer to the sporadic region E, and it is of interest to compare these values with equivalent heights of 113 and 130 km which have been put forward[2] as the noon values of the heights at which the sporadic region E is actually formed in June and December respectively.

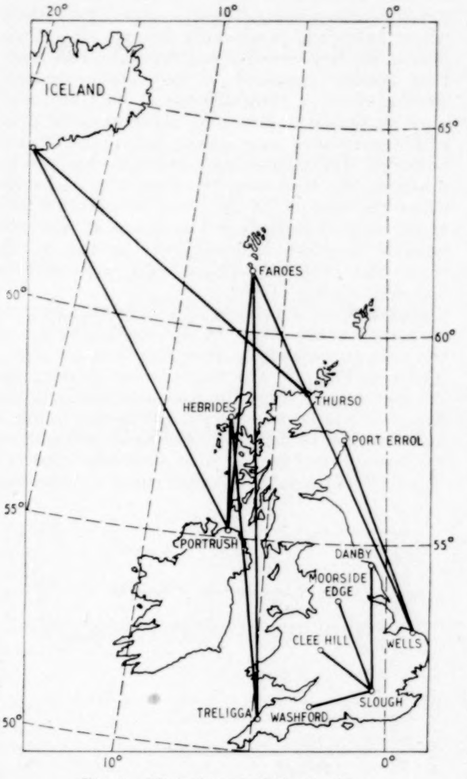


Fig. 1. *Map of transmission paths.*

### 4.2. *Measurements on B.B.C. Transmissions*

Throughout this whole series of tests vertical-incidence measurements were made at Slough and sporadic-region E echoes were observed most of the time.

In the first series, transmissions from Washford on 0·877 Mc/s were received at Slough consisting of a ground wave and one or more reflections from region E, all of comparable amplitude. The lowest echoes from region E show a well-marked maximum tendency to occur at a height of 106 km but the complete distribution of the heights of this echo is shown in Fig. 2. In addition to the reflection from about this height there was often evidence of stray reflections from a slightly higher level of about 120–130 km equivalent height. Measurements were also made on the second- and third-order reflections where possible and these confirm this higher level of reflection. It was found that although these multiple echoes sometimes yielded a value agreeing with the lower height (100–110 km) of the first echo, there was a tendency for them to give heights of reflection more closely corresponding to the higher level (120–130 km) even when this did not show on the first-order echo. This was due to the fact that if echoes were received simultaneously from both levels, the resolution available was frequently insufficient and only the lower level could be measured with accuracy on the first-order reflection. Evidence of stratification also appeared in the following observations. When the equivalent height of reflection was measured continuously on the same frequency (0·877 Mc/s) on transmissions over the two different path lengths (196 and 255 km) from Washford and Moorside Edge it was possible to observe the two different levels of reflection. The higher level was observed on the transmission over the shorter distance thereby indicating the usual type of penetration phenomenon. This comparison between the two paths was made on six nights during November 1943 between midnight and 0300 G.M.T. and multiple reflections were not observed. The results showed good agreement between the two trajectories; the most probable height of reflection was 107–108 km for Washford and 106 km for Moorside Edge transmissions.

### 4.3. *Measurements on Loran Transmissions*

The remainder of the measurements were made on the Loran frequencies over the varying distances shown in Table 1. The signal-noise ratio for the sky wave was a maximum at night whereas for the ground wave it was a maximum during the daytime. As simultaneous reception of ground and sky-wave is required for the measurement of the relative delay, the optimum periods for observation were usually the evening and early morning.

At all times and at all places there were considerable variations in the delay measurements. Over the shorter distances and during the night the variations were greatest as shown in the examples given in Fig. 3. Each point on the graph represents the mean of 10 observations taken at one-minute intervals, thus eliminating most of the rapid short-period variations which occur.

Care was taken to include only echoes from region E although it frequently happened, especially towards the end of the night, that the major amount of energy was reflected from region F. At times, two or more region-E echoes could be seen simultaneously and the first echo was often quite small compared with one of the others. Sometimes this first echo was observed to fade-out completely. When a major echo was observed with a greater delay than the first observable echo both were measured. The major echo is shown by a cross in Fig. **3** and any other echo measured, by a dot. No systematic diurnal variation in the delay time has been observed but often there is a sudden increase followed by a more gradual decrease. This is illustrated in Fig. 3(a) and (d). It is interesting to record that this effect is also frequently observed at vertical incidence, particularly in the morning.

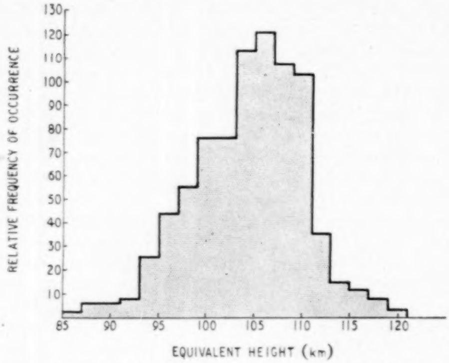


Fig. 2. *Distribution of reflection heights (first echo), Washford–Slough,* 1943, 0·887 *Mc/s.*

A striking feature was observed in the series of measurements made at Thurso in the North of Scotland on transmissions from the Faroes. This was the occurrence of small rapidly fluctuating echoes extending downwards through the major echo until they were masked by the direct way. This feature appeared to be associated with medium-distance transmissions at high latitudes since no similar observation has been noted over long distances, or over similar distances at lower latitudes. The phenomenon was also observed at Portrush on transmissions from the Hebrides where the latitude at the point of reflection was again high. Under such conditions it was not possible to make measurements on the lowest echo, and only the major echo was used as described above.

Distribution curves which show the relative frequency of occurrence of the observed delays of the echo at some of the observing sites are reproduced in Fig. 4. The most probable delay for the first echo, as shown by the distributions for all distances, has been extracted and plotted in Fig. 5 as a function of distance. The same information has been plotted in Fig. 6 to show the apparent height of reflection. The upper curve A represents

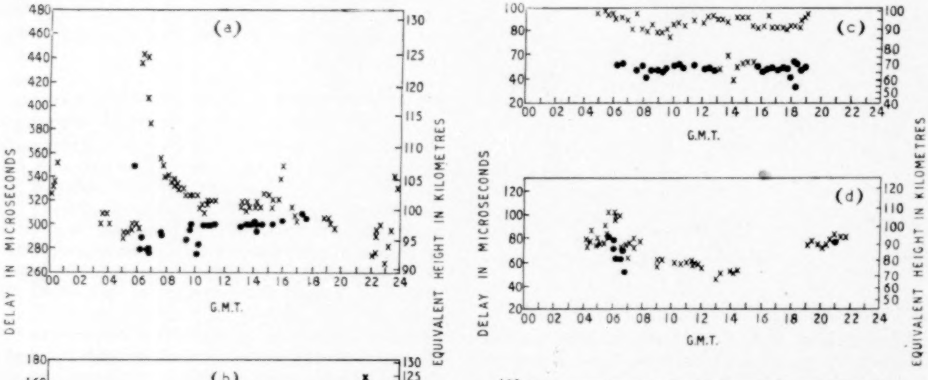


Fig. 3. *Relative delay on Loran frequencies: (a) distance* 170 *km,* 20*th*–21*st September,* 1944*; (b)* 693 *km,* 26*th*–27*th August,* 1944*; (c)* 854 *km,* 2*nd May,* 1944*; (d)* 1,053 *km,* 19*th*–20*th March,* 1944*; (e)* 1,208 *km,* 3*rd May,* 1944

the mean condition observed by night although similar values were observed to a lesser extent by day, whereas the lower curve B represents results which were only observed during daytime. On the same diagram are lines C and D showing the approximate equivalent heights observed in the measurements over shorter distances described in Section 4.2. The standard deviation of the individual delay values for the first observed echo has been calculated for night-time measurements and is shown as a function of distance in Fig. 7. It is seen that in the range 170–1,200 km its value falls from 22 to 9 microseconds. Fig. 8 shows the corresponding standard deviation of equivalent height, and this is seen to rise from 4·5 to 7·5 km over the range of distances used. In

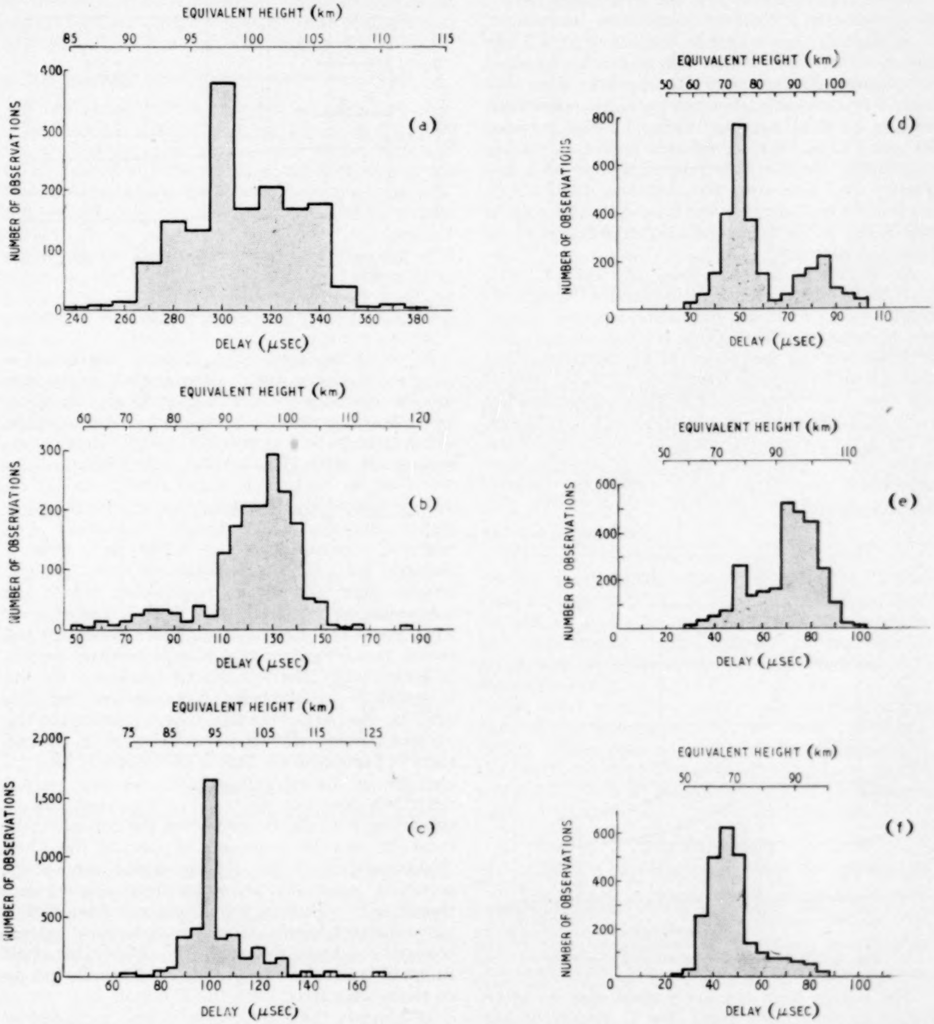


Fig. 4. *Relative frequency of occurrence of observed delays:* (*a*) *distance* 170 *km;* (*b*) 522 *km;* (*c*) 693 *km;* (*d*) 854 *km;* (*e*) 1,053 *km;* (*f*) 1,208 *km.*

the case of the measurements of delays from Faroes to Thurso and the Hebrides to Portrush, where the major echo had to be used, the standard deviations were found to be 42 and 43 microseconds, corresponding to 14 and 13 km equivalent height respectively.

## 5. Discussion

These results show that the equivalent height of ionospheric reflections at medium frequencies is subject to considerable variation at all the distances studied. When the first echo received is considered, however, it appears from the 2-Mc/s results that the most probable equivalent heights lie in a fairly well-defined range between 90 and 97 km. We regard this region as mainly responsible for the reflection of signals on a frequency of 2 Mc/s over the distances involved; it is effective both by day and by night, and may be associated with the meteoric layer referred to by Hey and Stewart.[3]

At distances greater than 500 km an echo corresponding to considerably smaller equivalent heights of 70 to 75 km frequently appears during the daytime. As the distance is increased from 500 to 1,200 km the frequency of its occurrence has been found to increase from 25% to about 70% of the time. No observation of such reflections has been made during hours of darkness but, as shown in Fig. 3(e) for example, this echo can constitute the major signal during daylight hours, even though reflections from the higher level are present simultaneously.

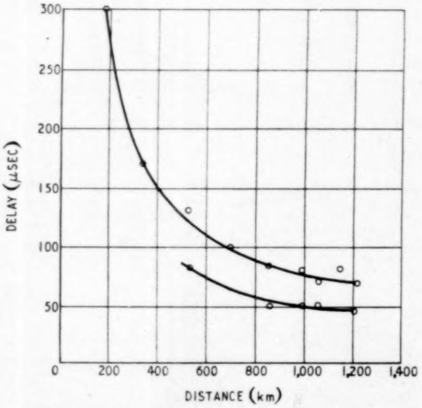


Fig. 5. *Most probable values of delay times.*

The echoes from the lower level may be attributed to reflections from the D region of the ionosphere. Examples of this phenomenon have been noted previously by various workers in different parts of the world, and a survey of such observations has been made by Ellyett.[4] A comparison may also be made with the work of Hollingworth[5] who showed that the height of reflection at the low frequency of 21 kc/s ($\lambda =$ 14,350 m) over distances similar to those concerned in the present paper was approximately 75 km by day, rising to 90 km by night.

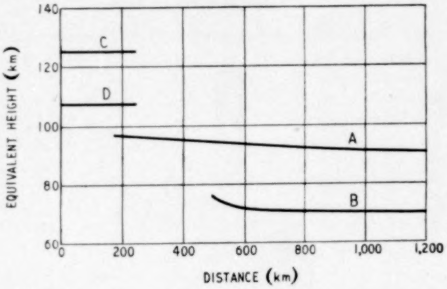


Fig. 6. *Variation of equivalent height with distance.*

In contrast with the 2-Mc/s results, the observations on lower frequencies and over shorter distances, including vertical incidence, have shown somewhat greater equivalent heights which tend to be concentrated roughly in the two ranges of 105–110 km and 120–130 km. As described in Section 2, these results should be simply related by Martyn's theorem to those on higher frequencies at longer distances. For example, transmissions on 0·668 Mc/s over a distance of 196 km (Washford to Slough) should give the same equivalent height as transmissions on 1·95 Mc/s over a distance of 1,000 km. The lack of such correspondence between the different sets of experimental results indicates that the conditions assumed in the formulation of Martyn's theorem are not fulfilled by the part of the ionosphere involved in the present studies. The theorem is based on the ray theory of propagation, which assumes only gradual changes in the refractive index, so that partial reflection does not occur. The experimental results described above show that partial reflection must in fact be regarded as one of the chief characteristics of the region of the ionosphere involved, especially at night-time; echoes may therefore be obtained simultaneously from two or more distinct levels. On some occasions, indeed, echoes have been observed over almost the whole range of equivalent heights from about 90 km up to those associated with the F region.

It appears that the region is best regarded as being irregularly stratified with cloudlike formations of ionization at various levels. With such a structure the change in equivalent height with angle of incidence can be explained on the assumption that the lower part of the region becomes more and more effective as the angle of incidence is increased. Thus a greater proportion of reflections will occur from the lower levels than may be expected from short-range experiments, although there is ample evidence that the upper levels can also be effective at longer distances, as shown by the examples of night-time observations in Fig. 3(a), (c) and (d), and in Fig. 4(b).

## 6. Conclusions

Time delay measurements at medium frequencies (0·7–2 Mc/s) over distances up to 1,200 km enable the structure in, and below, region E to be studied in some detail. Such a study reveals the existence of a considerable degree of stratification resulting in partial reflection of the incident energy. It is, therefore, important to consider separately the heights of reflection of the first echo received, and of the major echo. The first echo corresponds to a fairly well defined region giving a range of equivalent heights of 90 to 97 km, and this region is effective both by day and by night.

There are three other regions which are effective at certain times. The lowest is situated at an equivalent height of 70–76 km and may be identified with that responsible for the reflections on the much lower frequency of 21 kc/s already reported by Hollingworth. This region appears only to exist in the daytime, since no echoes were recorded from it at night.

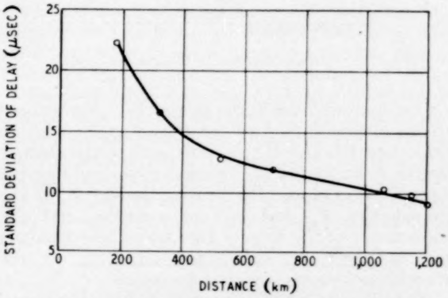


Fig. 7. *Standard deviation of a single measurement of delay.*

The stratum at 105–110 km lies just below the average level of the night-time sporadic region E observed at vertical incidence, and may therefore be associated with it.

When there is insufficient ionization present in the lower strata, penetration to a level of about 125 km occurs. In the present experiments there were no occasions on which all four strata were so completely penetrated that no echoes at all were observed from one, or other, of the regions shown in Fig. 6.

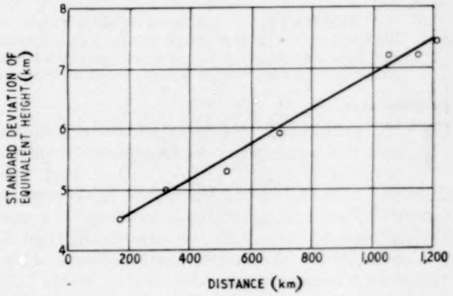


Fig. 8. *Standard deviation of a single measurement of equivalent height.*

The structure revealed by these measurements invalidates the use of Martyn's theorem in the computation of transmission paths at oblique incidence from vertical-incidence measurements. It shows that the phenomenon of partial reflection is an important factor in the determination of propagation conditions on medium frequencies over distances at least up to 1,200 km.

## Acknowledgments

We wish to acknowledge the help of Mr. G. J. Burtt of the Admiralty Signals and Radar Establishment, Mr. C. F. Sutton of Signals Plans, Air Ministry, in planning and executing the work, and the British Broadcasting Corporation for arranging the transmissions from Washford and Moorside Edge.

The work described above was carried out as part of the programme of the Radio Research Board. This paper is published by permission of the Director of the National Physical Laboratory, and the Director of Radio Research of the Department of Scientific and Industrial Research.

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# POWER METER AND MISMATCH INDICATOR

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**SUMMARY.**—A simple directional power meter is described for the band 150-250 Mc/s. Both forward and reflected power are indicated simultaneously which makes the instrument very suitable for load matching. A linear scale indicates 10 W at full-scale deflection with negligible loading of the transmission line. Other power ranges and frequency bands may be obtained.

## Introduction

THE problem of matching a load to a source and the subsequent measurement of power transfer is not a simple one at high frequencies. Owing to the uncertain knowledge of circuit values and matching conditions it is not satisfactory to substitute an absorbent type of power meter for the normal working load. It is, therefore, necessary to determine either the standing-wave conditions in the transmission line or, in the case of a transmitter, the radiated field strength. A section of slotted line having the same impedance as the transmission line is commonly inserted for the former purpose. This permits use of a travelling detector to delineate the standing-wave pattern, a method which yields excellent results but becomes rather laborious since the wave pattern must be retraced after each matching adjustment before the effect is seen.

Further, the apparatus is both expensive and bulky (at least half a wavelength long) and, for power measurements, the detector must be calibrated by reference to another instrument. A physically-small instrument which is simpler to use and less expensive to construct is the 'directional power meter' described below.

Transmitted and reflected power are each directly indicated without adjustment and the matching procedure may, therefore, be carried out with celerity.

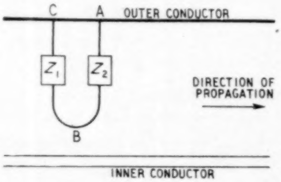

Fig. 1. *Schematic diagram of directional coupler.*

## The Directional Coupler

The basis of the method is the directional coupler which consists essentially of a loop, of dimensions small compared with wavelength, which is inserted into a short section of coaxial line and loosely coupled to both the electric and magnetic fields. The phase and magnitudes of the respective components are chosen so that cancellation is obtained for a wave travelling in one direction and addition in the other. In Fig. 1 the currents flowing through the impedances $Z_1$ and $Z_2$ have two components.

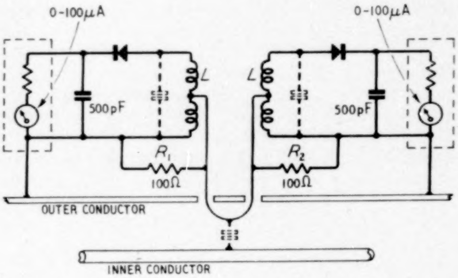

Fig. 2. *Circuit diagram of directional coupler.*

One current flows in the sense ABC proportional to the magnetic field vector $H$ and another in the directions BC and BA proportional to the electric vector $E$ by virtue of the capacitive coupling between the loop and the centre conductor. If the impedances $Z_1$ and $Z_2$ are resistive and the inductance of the loop is negligible these currents are in phase or anti-phase according to the direction of propagation of the wave.

The net currents flowing in $Z_1$ and $Z_2$ are, therefore, the sum and difference respectively of the currents derived from each component and, if the loop is proportioned or orientated so that the coupling to both components is equal, cancellation will occur in one branch. A means is thereby provided of completely separating responses to forward and reflected waves, limited only by the accuracy with which a practical balance can be achieved. Discrimination against power flowing in the reverse direction may easily be made to exceed 20 db, while with special precautions figures of 40 db or more are possible.

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MS accepted by the Editor, August 1950

## The Power Meter

In Fig. 2 a practical circuit is shown of an instrument which has been successfully employed in the band 150-250 Mc/s. The inductances $L$ are tuned by stray capacitances to the approximate centre of the working band and are heavily damped by the resistances $R_1$ and $R_2$. Sensitivity and bandwidth are interchangeable and the position of the tapping points on the coils depends on the performance required. The crystal rectifiers employed are approximately square law and, therefore, provide a scale shape which is practically linear in terms of power. It is a disadvantage that, quite apart from bandwidth considerations, the calibration is frequency sensitive. This arises fundamentally since the e.m.f. generated in a loop depends on the rate of change of flux. However, the effect is exactly calculable and readings taken at frequencies different from the calibration frequency are easily corrected. The physical construction is illustrated in the photographs of Fig. 3 and 4 and the sketches of Fig. 5.

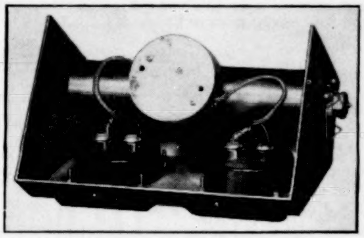

Fig. 3. *Back view of power indicator.*

The loop (shown in Fig. 5) is supported inside a brass tube and the associated coils, crystals and capacitors are housed in a circular box which is partitioned by a brass screen into two compartments. Resistors are soldered directly between the loop and the tube close to the point of entry into the coaxial section. The whole loop assembly slides within another tube projecting perpendicularly from the coaxial section and a screw clamp is provided so that the loop may be locked in position at any desired depth and orientation. The coaxial section is fitted with a Pye plug at each end for convenient insertion into the circuit under test.

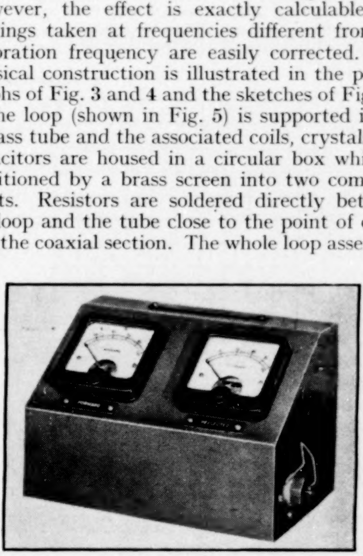

Fig. 4. *Front view of complete instrument.*

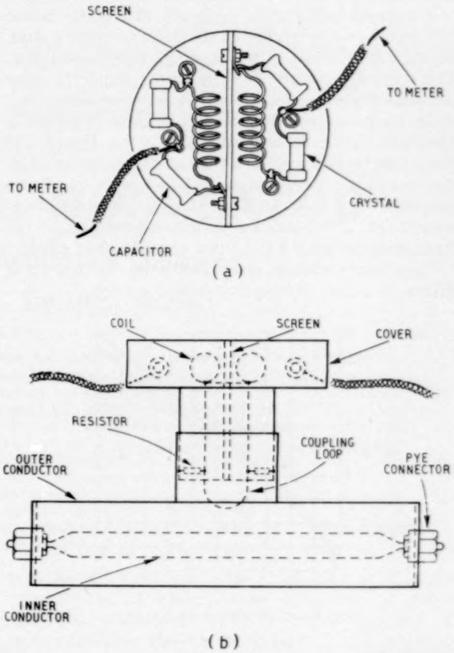

Fig. 5. *Physical layout of directional coupler. A plan view (with cover removed) is shown at (a) and the side elevation at (b).*

## Adjustment and Calibration

A source is required which will deliver power at the level desired for full-scale deflection of the instrument and also a matched power meter of known characteristics. The directional coupler and its associated section of line are connected between the source and power meter. Under these conditions there is no reflected power and a position of the loop should be found where the indicated reflected power is zero and the 'forward-power' instrument is at full scale. The accuracy of the match provided by the terminating power meter may be checked at this stage by inserting a further quarter wavelength of line between that instrument and the directional coupler. If the indicated reflected power remains at zero the termination is satisfactory. A calibration of the 'forward-power' meter may now be obtained by reducing the input power in steps and plotting meter readings against levels measured on the reference power meter. The 'reflected-power' meter is calibrated in precisely the same way by reversing connections so that the wave passes the coupling loop in the reverse direction and so appears in effect as a totally-reflected wave.

A typical calibration is shown in Fig. 6. Some care is necessary during calibration to ensure that strong harmonics of the source do not cause error. The tuned circuits of the directional coupler provide some measure of protection against low-order harmonics and if the reference instrument is aperiodic some discrepancies may be found. It must also be remembered that as mentioned earlier the coupling increases with frequency, and the presence of a parasitic oscillation in the power source at a frequency much higher than the fundamental may have very considerable effect.

Conclusive checks may be made by inserting filters or using alternative power sources.

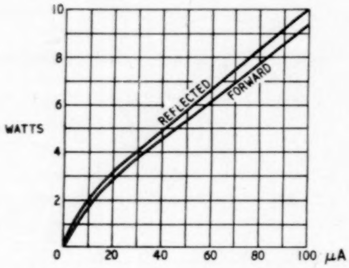

Fig. 6. *Calibration at 200 Mc/s.*

## Conclusion

A compact instrument has been designed and constructed for the measurement of power flowing through a transmission line while absorbing very little power and causing negligible reflection.

An instantaneous indication is given of both forward and reflected power, so that net transmitted power is obtained by subtraction and the effects of matching adjustments are seen at once. A model for the frequency range 150-250 Mc/s, indicating 10 W full-scale deflection has been in use for some time and proved fully satisfactory.

## Acknowledgments

The instrument described here represents an extension of a device described by Messrs. Allen and Curling in Reference 1, who supply in the same paper a most adequate account of the theoretical design.

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## APPENDIX

### LOOP DIMENSIONS AND SENSITIVITY

Since the penetration of the loop into the line is adjustable over a wide range only an approximate estimate of the dimensions is necessary. In the interests of stability and ease of adjustment it is desirable to avoid the region of intense fields near the centre conductor, and penetration to a maximum depth equal to one half the radius of the outer conductor is regarded as a design criterion for coaxial lines of 75 ohms impedance.

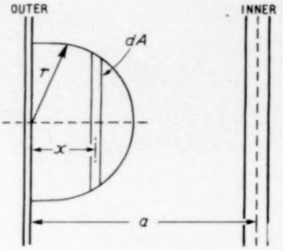

Fig. 7. *Loop dimensions.*

The following analysis derives an expression for the e.m.f. induced in a semi-circular loop when orientated for maximum coupling to the magnetic field. No attempt has been made to compute the more difficult coefficient of electric coupling since this may easily be adjusted experimentally with only minor disturbance of the design.

In Fig. 7 a current $I$ flows in the centre conductor. If the resultant magnetic field is designated by $H$ the e.m.f. $V$ induced in the loop is given by:—

$$V = \int \mu_o \frac{dH}{dt} \cdot dA \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (1)$$

where all quantities are measured in m.k.s. units and $\mu_o = 4\pi \times 10^{-7}$.

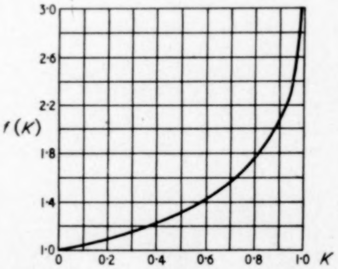

Fig. 8. *Graph of f(K).*

Now $H = \dfrac{I}{2\pi(a - x)}$ and $dA = 2\sqrt{r^2 - x^2} \cdot dx$.

$$\therefore V = \frac{\mu_o}{\pi} \cdot \frac{dI}{dt} \cdot \int_o^r \frac{\sqrt{r^2 - x^2}}{a - x} \cdot dx. \quad \ldots \quad \ldots \qquad (2)$$

The substitution of $x = r \sin \theta$ and $K = r/a$ transforms this into:—

$$V = \frac{\mu_o}{\pi} \cdot \frac{dI}{dt} \cdot K^2 a \int_o^{\pi/2} \frac{\cos^2 \theta}{1 - K \sin \theta} d\theta \quad \ldots \qquad (3)$$

So that (2) may be expressed:—

$$V = \frac{j\omega I\mu_0}{\pi} \cdot \frac{K^2 a.\pi}{4} \cdot f(K) \quad \ldots \quad \ldots \quad \ldots \qquad (4)$$

where $I$ is assumed sinusoidal

$$\text{and } f(K) = \frac{4}{\pi}\int_0^{\pi/2} \frac{\cos^2\theta}{1 - K\sin\theta} \cdot d\theta$$

$$= \frac{4}{\pi}\int_0^{\pi/2} \cos^2\theta \left[1 + K\sin\theta + K^2\sin^2\theta + \ldots\ldots\ldots\right] d\theta$$

$$= 1 + \frac{4}{3\pi}K + \frac{1}{4}K^2 + \frac{8}{15\pi}K^3 + \frac{1}{8}K^4 + \ldots.$$

This function $f(K)$ is shown graphically in Fig. 8.

It is seen from (4) that sensitivity depends on the values of both $K$ and $a$. If for design purposes $K$ is chosen at 0·5 then we have:—

$$V \approx 0{\cdot}08 j\omega\mu_0 Ia$$

Here the value of $a$ may be selected to yield the desired sensitivity, bearing in mind the bandwidth required and hence the gain afforded by the tuned circuits.

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# THE MAGNETIC MODULATOR

## *Even-Harmonic Modulation Theory*

**By R. Feinberg, Dr.Ing., M.Sc.**

*(Ferranti, Ltd.)*

**SUMMARY.**—The magnetic modulator of the even-harmonic type is a simple and robust device for efficiently converting a weak direct current to a linearly proportional alternating voltage or current, the phase of the output voltage or current discriminating between positive and negative values of the input direct current. Optimum modulator performance is obtained with a transductor whose core material has a magnetization curve with a narrow hysteresis loop, a sharp bend at the knee and a high initial permeability, and with a sinusoidal transductor voltage of such magnitude that the peak value of the alternating magnetic-flux density component in the transductor core is equal to the value of flux density at the knee of the magnetization curve. The modulator output characteristic is virtually linear in the lower range of control current. At a large control current the output voltage is virtually independent of control current when the modulator is in no-load condition, whereas the output current is virtually zero when the modulator is in short-circuit condition. The phases of output voltage and output current, respectively, change by 180° when the polarity of the control current is changed.

### 1. Introduction

A MAGNETIC modulator of the even-harmonic type is a circuit arrangement based on a transductor, and is an effective practical device for converting a weak direct current to a corresponding alternating voltage or alternating current.[1] A general theoretical treatment of the performance of the modulator is intricate and laborious. It is, however, possible to draw significant and satisfactory conclusions by considering special cases of modulator operation more easily accessible to mathematical treatment.

So far, modulator operation has been considered theoretically for a transductor with sinusoidal current and no-load modulator output,[2,3] and for a transductor with triangular current and no-load modulator output.[4] In this paper a theory is presented of the modulator with sinusoidal transductor voltage and no-load output as well as short-circuit output.

### 2. Circuit Arrangement

Fig. 1 shows the circuit arrangement of the modulator. The auxiliary a.c. power supply 1 is connected to the a.c. excitation coils 2(b) of the transductor 2 whose cores 2(a) are of ferromagnetic material. The control current $I_c$ passes through the control coils 2(c) and produces in the transductor cores a d.c. bias flux $\Phi_c$.

The magnetizations of the two transductor cores are unsymmetrical with the result that an alternating voltage $V_2$, of twice the frequency of the a.c. supply voltage $V_1$, is produced across the output coils 2(d). The magnitude of $V_2$ is an optimum when the control current is smooth. Smoothness of $I_c$ may be obtained, for example, by inserting an inductor 3 in the control circuit of the transductor, see Fig. 1. $V_2$ is varied by varying $I_c$.

### 3. No-Load Modulator Characteristic

The modulator characteristic in no-load condition means the relation between the voltage $V_2$ (Fig. 1) of the modulator in open circuit and the direct current $I_c$. The assumptions for calculation are: (a) the magnetization characteristic of the

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core material is represented by a combination of straight lines joining one another in a sharp bend at the knee of the characteristic; (b) the magnetic paths of the transductor cores have no air-gaps and are of uniform sectional area; (c) the transductor has no leakage flux or iron or copper losses; and (d) the auxiliary a.c. supply voltage $v_1$ is sinusoidal; i.e.,

$$v_1 = V_1\sqrt{2}\cos\omega t \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Let $v'_1$ and $v''_1$ be the voltages across the a.c. excitation coils 2(b), see Fig. 1, and $v'_2$ and $v''_2$ the voltages across the output coils 2(d). Then

$$v_1 = v'_1 + v''_1$$

$$= N_1 A \frac{d}{dt}(b' + b'') \quad \ldots \quad \ldots \quad (2)$$

and

$$v_2 = -v'_2 + v''_2$$

$$= N_2 A \frac{d}{dt}(-b' + b'') \quad \ldots \quad \ldots \quad (3)$$

where $N_1$ and $N_2$ denote, respectively, the number of turns of an excitation coil and an output coil, $A$ is the sectional area of a transductor core, and $b' = (\phi' + \Phi_c)/A$ and $b'' = (\phi'' - \Phi_c)/A$ are the magnetic flux densities in the two cores (see Fig. 1).

For further discussion it is convenient to designate

$$b_1 = b' + b'' \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

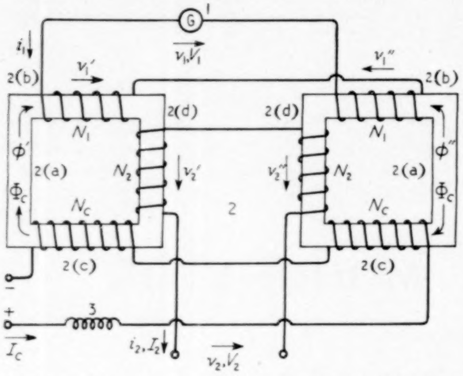


Fig. 1. *Magnetic converter of direct current to alternating current with frequency-doubled output:* 1, *Auxiliary a.c. power supply;* 2, *Transductor,* 2 (a), *cores,* 2 (b), *a.c. excitation coils,* 2 (c), *control coils,* 2 (d), *output coils;* 3, *Inductor representing high impedance in control circuit.*

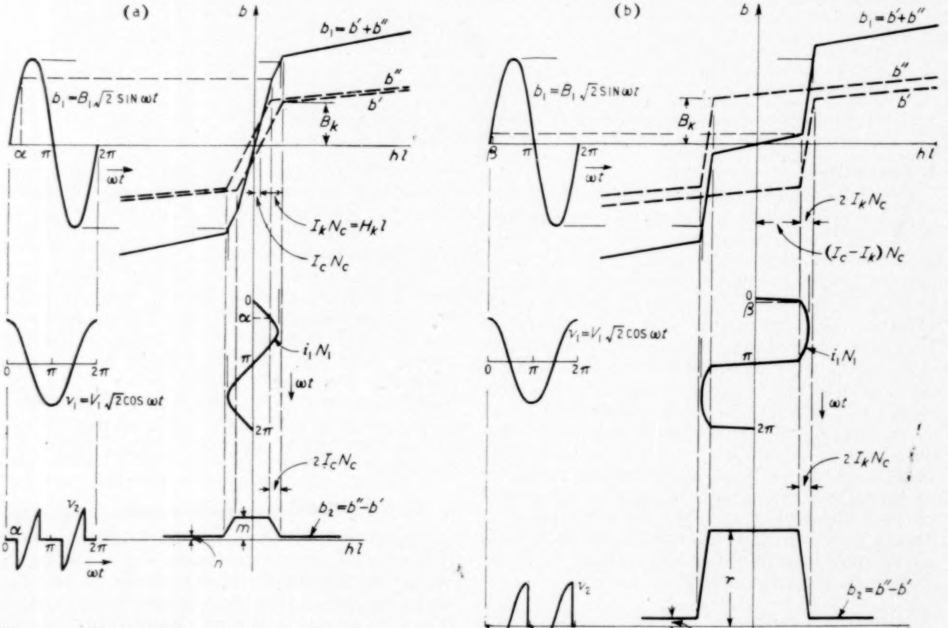


Fig. 2. *Virtual magnetization characteristics of the transductor and output voltage at no-load:* (a) $I_c < I_k$, (b) $I_c > I_k$.

as the virtual magnetic-flux density for the excitation winding 2(b) of the transductor (Fig. 1),

and $b_2 = b'' - b'$ .. .. .. .. (5)

as the virtual magnetic flux density for the output winding 2(d). Fig. 2(a) and (b) show $b_1$ and $b_2$ as functions of the ampere-turns $h.l$ of a core, where $h$ is the magnetizing force and $l$ the length of the magnetic path of a core. Because of the sinusoidal voltage $v_1$, see equation (1), across the excitation winding of the transductor we have

$$b_1 = B_1\sqrt{2}\sin\omega t \quad .. \quad .. \quad .. \quad (6)$$

$$\text{with} \quad B_1 = \frac{V_1}{\omega N_1 A} \quad .. \quad .. \quad .. \quad .. \quad (7)$$

Fig. 2(a) shows voltages, magnetic-flux densities, and ampere-turns when $I_c < I_k$, and Fig. 2(b) when $I_c > I_k$ where $I_k$ is defined by the relation

$$I_k = \frac{H_k \,.\, l}{N_c} \quad .. \quad .. \quad .. \quad .. \quad (8)$$

with $H_k$ denoting the magnetizing force at the knee of the magnetization characteristic of the core material [see Fig. 2(a)] and $N_c$ the number of turns of a control coil (Fig. 1).

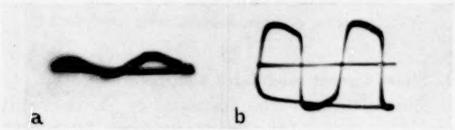


Fig. 3. *Oscillograms of the alternating excitation current at no-load: (a) $I_c < I_k$, (b) $I_c > I_k$.*

Fig. 2(a) and (b) also shows the waveshapes of the alternating excitation current $i_1$ and of the output voltage $v_2$ at no-load. The theoretical curves are verified, respectively, by the oscillograms in Fig. 3 for the alternating excitation current $i_1$ and in Fig. 4 for the output voltage $v_2$. The oscillogram in Fig. 5 shows the phase reversal of $v_2$ at changed polarity of the direct current $I_c$.

The output voltage $v_2$ is calculated from the basic relation, see equations (3) and (5),

$$v_2 = N_2 A \frac{db_2}{dt} \quad .. \quad .. \quad .. \quad .. \quad (9)$$

For $I_c \leqslant I_k$ we have for a half-period of $b_2$, with the notation of Fig. 2(a), the expressions

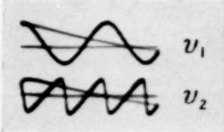
$$b_2 \Big|_{o}^{\alpha} \Big|_{\pi-\alpha}^{\pi} = m = \text{const.} \quad .. \quad .. \quad .. \quad (10)$$

and, see Appendix, Section 1,

$$b_2 \Big|_{\alpha}^{\pi-\alpha} = m - \frac{(\mu_1 - \mu_2)\mu_o}{l} \,.\, i_1 N_1 \Big|_{\alpha}^{\pi-\alpha} \quad .. \quad (11)$$

with, from Fig. 2(a),

$$i_1 N_1 \Big|_{\alpha}^{\pi-\alpha} = \frac{B_1\sqrt{2}\sin\alpha}{2\mu_1\mu_o} \,.\, l + \frac{B_1\sqrt{2}(\sin\omega t - \sin\alpha)}{(\mu_1 + \mu_2)\mu_o} \,.\, l \quad .. \quad .. \quad (12)$$



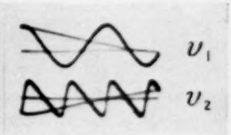


Fig. 4 (left). *Oscillogram of the output voltage at no-load and positive control current.*

Fig. 5 (right). *Oscillogram of the output voltage at no-load and negative control current.*

The symbol $\mu_1$ denotes the relative permeability of the non-saturation region of the magnetization characteristic of the core material, $\mu_2$ the incremental permeability of the saturation region, and $\mu_o = 0{\cdot}4\pi \times 10^{-6}$ henry/metre the absolute permeability of free space expressed in the rationalized form of the m.k.s. system of units. Let us introduce the magnetic-flux density factor

$$k_s = \frac{B_1\sqrt{2}}{2B_k} \quad .. \quad .. \quad .. \quad .. \quad (13)$$

where $B_k$ is the magnetic-flux density at the knee of the magnetization characteristic of the core material, see Fig. 2(a). From equation (9) we obtain with equations (10) to (13)

$$v_2 \Big|_{o}^{\alpha} \Big|_{\pi-\alpha}^{\pi} = 0 \quad .. \quad .. \quad .. \quad .. \quad (14)$$

and

$$v_2 \Big|_{\alpha}^{\pi-\alpha} = - N_2 A k_s B_k \frac{\mu_1 - \mu_2}{\mu_1 + \mu_2} 2\omega\cos\omega t \,.. \quad (15)$$

The mean value $V_2$, measured with a rectifier instrument, is derived, with the notation of Fig. 2(a), from the relation

$$V_2 = - \frac{2}{\pi}\int_{o}^{\pi/2} v_2 d\omega t \quad .. \quad .. \quad .. \quad (16)$$

From Fig. 2(a), with equations (8) and (13) and $B_k = \mu_1\mu_o H_k = \mu_1\mu_o I_k I_c / l$, we have

$$\sin\alpha = \frac{(I_k - I_c)N_c}{B_1\sqrt{2}}\,\frac{2\mu_1\mu_o}{l} = \frac{1}{k_s}\left(1 - \frac{I_c}{I_k}\right) \quad (17)$$

Therefore, from equations (16) with (15), (13) and (7), if $I_c/I_k > (1 - k_s)$ and $0 \leqslant k_s \leqslant 1$,

$$\frac{V_2}{V_1}\frac{N_1}{N_2} = \frac{2\sqrt{2}}{\pi}\frac{\mu_1 - \mu_2}{\mu_1 + \mu_2}\frac{1}{k_s}\left[\frac{I_c}{I_k} - (1 - k_s)\right] \quad .. \quad (18)$$

For $I_c/I_k \leqslant (1 - k_s)$, we have $V_2/V_1 = 0$.

For $I_c \geqslant I_k$ we have, with the notation of Fig. 2(b), for a half-period of $b_2$

$$b_2\Big|_{o}^{\beta}\Big|_{\pi-\beta}^{\pi} = r = \text{const.} \quad .. \quad .. \quad .. \quad (19)$$

and, see Appendix, Section 2,

$$b_2\Big|_{\beta}^{\pi-\beta} = r - \frac{(\mu_1 - \mu_2)\mu_o}{l} \, . \, i_1N_1\Big|_{\beta}^{\pi-\beta} \quad .. \quad (20)$$

with, from Fig. 2(b),

$$i_1N_1\Big|_{\beta}^{\pi-\beta} = \frac{B_1\sqrt{2}\sin\beta}{2\mu_2\mu_o}\, . \, l + \frac{B_1\sqrt{2}(\sin\omega t - \sin\beta)}{(\mu_1 + \mu_2)\mu_o}\, . \, l \quad .. \quad .. \quad (21)$$

From equation (9) we obtain, with equations (19) to (21) and (13)

$$v_2\Big|_{o}^{\beta}\Big|_{\pi-\beta}^{\pi} = 0 \quad .. \quad .. \quad .. \quad .. \quad (22)$$

and

$$v_2\Big|_{\beta}^{\pi-\beta} = -N_2Ak_sB_k\frac{\mu_1 - \mu_2}{\mu_1 + \mu_2}2\omega\cos\omega t \quad .. \quad (23)$$

From Fig. 2(b), similarly to the derivation of equation (17),

$$\sin\beta = \frac{(I_c - I_k)N_c}{B_1\sqrt{2}}\frac{2\mu_2\mu_o}{l} = \frac{1}{k_s}\frac{\mu_2}{\mu_1}\left(\frac{I_c}{I_k} - 1\right) \quad .. \quad .. \quad (24)$$

Integration of equation (16) with (22) to (24) and (7) gives for $V_2$

$$\frac{V_2}{V_1}\frac{N_1}{N_2} = \frac{2\sqrt{2}}{\pi}\frac{\mu_1 - \mu_2}{\mu_1 + \mu_2}\left[1 - \frac{1}{k_s}\frac{\mu_2}{\mu_1}\left(\frac{I_c}{I_k} - 1\right)\right] \quad .. \quad .. \quad .. \quad .. \quad (25)$$

Fig. 6(a) shows curves of $(V_2/V_1) \cdot (N_1/N_2)$ calculated for $\mu_2/\mu_1 < 0{\cdot}01$ with $k_s$ as parameter. The experimental curve of Fig. 6(b) was obtained with Mumetal cores, $75 \times 50 \times 20 \times 0{\cdot}2$ mm, $N_1 = 200$, $N_2 = 400$, $N_c = 200$, $V_1 = 7{\cdot}5$ V. The experimental results are in fair accord with the corresponding theoretical curve, $k_s = 1$, in Fig. 6(a), considering the substantial simplifications made for the calculation.

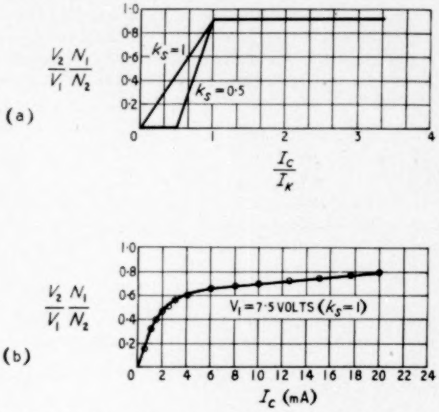


Fig. 6. *Output voltage characteristic at no-load: (a) theoretical curves, (b) experimental curve for* $k_s = 1$.

## 4. Short-Circuit Modulator Characteristic

The modulator characteristic in short-circuit condition means the relation between the output current $I_2$ (Fig. 1) of the modulator in short-circuit and the direct current $I_c$. The assumptions for calculation are the same as stated in the first paragraph of Section (3).

Fig. 7 shows the magnetic-flux densities, $b' = B_o + 0{\cdot}5B_1\sqrt{2}\sin\omega t$ and $b'' = -B_o + 0{\cdot}5B_1\sqrt{2}\sin\omega t$, of the two transductor cores (Fig. 1) and the corresponding magnetizing ampere-turns, $h'.l$ and $h''.l$, for the modulator with the output in short-circuit, $h'$ and $h''$ denoting the magnetizing forces in the cores, $l$ the length of magnetic path in a core, $B_o$ and $-B_o$ the mean values of magnetic-flux densities in the cores, and $B_1$ [see equation (7)], the r.m.s. value of the sinusoidal magnetic flux density component in a core.

The ampere-turns $h'.l$ and $h''.l$ (Fig. 7) consist of odd-harmonic components and even-harmonic components. The odd-harmonic current components required to produce the odd-harmonic ampere-turn components of $h'.l$ and $h''.l$ are carried in the excitation coils 2(b), see Fig. 1, of the transductor; they form the current $i_1$ in the auxiliary power-supply circuit. The even-harmonic current components required to produce the even-harmonic ampere-turn components of $h'.l$ and $h''.l$ constitute the short-circuit current $i_2$ carried in the output coils 2(d) (Fig. 1). Fig. 7

shows a typical waveshape of $i_2$, for $I_c > 0$. When $I_c < 0$, the phase of $i_2$ is reversed. The oscillograms of Fig. 8 give the current $i_1$ in the excitation coils and the current $i_2$ in the output coils at short-circuit, for $I_c > 0$.

To calculate $I_2$ we analyze $i_2$ into a Fourier series. We have, with the notation of Fig. 7,

$$i_2 = \sum_n^{\infty} I_{2(n)}\sqrt{2} \cos n\omega t \; (n = 2,4,6\ldots) \quad .. \quad (26)$$

and

$$I_2 = \sqrt{\sum_n^{\infty} I_2^2{}_{(n)}} \quad (n = 2,4,6\ldots) \quad .. \quad (27)$$

where, with the notation of Fig. 7 and equation (13),

$$I_{2(n)}N_2 = H_n.l \qquad (n = 2,4,6\ldots)$$

$$= \frac{1}{\sqrt{2}}\frac{1}{\pi}\int_o^{2\pi} h'.l \cos n\omega t d\omega t$$

$$= \frac{1}{\sqrt{2}}\frac{k_s B_k l}{\mu_2\mu_o}\frac{2 \sin n\gamma \cos \gamma - 2n \cos n\gamma \sin \gamma}{n(n^2-1)\pi}$$

$$\left(1 - \frac{\mu_2}{\mu_1}\right) \quad .. \quad .. \quad .. \quad (28)$$

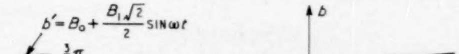


Fig. 7. *Magnetization characteristics of the transductor cores and output current at short-circuit.*

with the parameter $\gamma$, see Fig. 7, defined by the relation

$$\cos\gamma = \frac{2(B_o - B_k)}{B_1\sqrt{2}} \quad (\pi \geqslant \gamma \geqslant 0) \quad .. \quad (29)$$

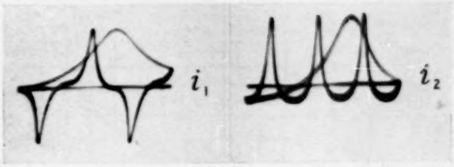


Fig. 8. *Oscillograms of alternating excitation current and output current at short-circuit.*

It is necessary to express the direct current $I_c$ in terms of the parameter $\gamma$ [equation (29)]. With the notation of Fig. 7 and equation (13), we have for $I_cN_c \geqslant (1 - k_s)B_k.l/(\mu_1\mu_o)$ the relation $I_cN_c = H_o.l$

$$= \frac{1}{2\pi}\int_o^{2\pi} h'.l d\omega t$$

$$= \frac{B_k.l}{\mu_2\mu_o}\left[\frac{\mu_2}{\mu_1} + k_s\left(\frac{\pi-\gamma}{\pi}\cos\gamma + \frac{\sin\gamma}{\pi} + \frac{\mu_2}{\mu_1}\frac{\gamma\cos\gamma - \sin\gamma}{\pi}\right)\right] \quad .. \quad (30)$$

For $I_cN_c \leqslant (1 - k_s)B_k.l/(\mu_1\mu_o)$ we have $I_2 = 0$.

The graphs of Fig. 9(a) are calculated from equations (27) to (30) for $\mu_2/\mu_1 = 0$ and $\mu_2/\mu_1 = 0{\cdot}01$ with $k_s$ [equation (13) and Fig. 7] as parameter. The theoretical curves are reasonably verified by the experimental curves of Fig. 9(b) which were obtained with a transductor as before, but with $N_1 = N_2 = 400$ and $N_c = 200$.

## 5. Conclusions

The magnetic modulator of the even-harmonic type, when operated with a sinusoidal transductor voltage, has a virtually linear control characteristic in the lower range of control current, the characteristic rising from the origin of the co-ordinate system if the transductor voltage has such magnitude that the peak value of the alternating magnetic-flux density component in the transductor cores is equal to the value of flux density at the knee of the magnetization curve. The device is useful in the low-current range of control for converting a weak direct current to a linearly proportional alternating voltage or a linearly proportional alternating current. A large control current produces a virtually constant output voltage when the modulator output circuit is open, but a virtually zero output current when the modulator output is in short-circuit. The phases of output voltage and output current, respectively, discriminate between positive and negative values of the input direct current, a change of the polarity of the control current causing the phases to change by 180°.

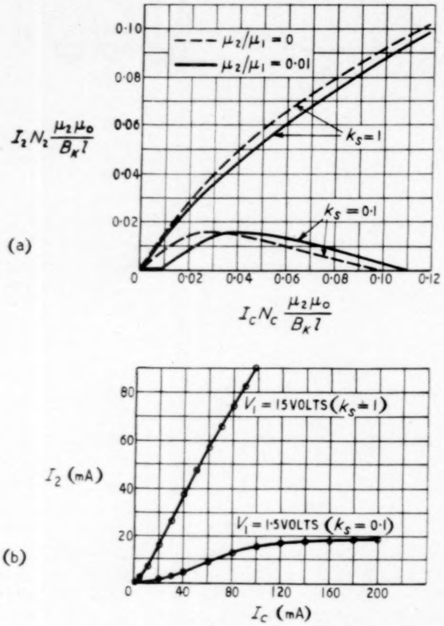


Fig. 9. *Output current characteristics at short-circuit: (a) theoretical curves, (b) experimental curves.*

## APPENDIX

**1.** From Fig. 2(a)

$$b_2\Big|_{\alpha}^{\pi-\alpha} = m - \frac{m-n}{2I_cN_c}\,.\,i_1N_1\Big|_{\alpha}^{\pi-\alpha} \qquad \ldots \quad \ldots \quad \ldots \quad (A.1)$$

Now we have

$$m = 2I_cN_c\,\frac{\mu_1\mu_o}{l} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (A.2)$$

and

$$n = 2I_cN_c\,\frac{\mu_2\mu_o}{l} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (A.3)$$

Therefore,

$$\frac{m-n}{2I_cN_c} = \frac{(\mu_1-\mu_2)\mu_o}{l} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (A.4)$$

and hence equation (11).

**2.** From Fig. 2(b)

$$b_2\Big|_{\beta}^{\pi-\beta} = r - \frac{r-s}{2I_kN_c}\,.\,i_1N_1\Big|_{\beta}^{\pi-\beta} \qquad \ldots \quad \ldots \quad \ldots \quad (A.5)$$

We have

$$r = 2\left[I_o\,\frac{\mu_2\mu_o}{l} + I_k\,\frac{(\mu_1-\mu_2)\mu_o)}{l}\right]N_c \qquad \ldots \quad (A.6)$$

and

$$s = 2I_cN_c\,\frac{\mu_2\mu_o}{l} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (A.7)$$

Therefore,

$$\frac{r-s}{2I_kN_c} = \frac{(\mu_1-\mu_2)\mu_o}{l} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (A.8)$$

and hence equation (20) from (A.5).

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## TECHNICAL PUBLICATIONS

### British Standard for Graphical Symbols used in Waveguide Technique

Supplement No. 2, 1951, to B.S. 530. British Standards Institution, Sales Dept., 24 Victoria St., London, S.W.1. Price 3s. (post free).

### Report of the Radio Research Board for 1949

Pp. 54. H.M. Stationery Office, York House, Kingsway, London, W.C.2. Price 1s. 9d. (postage 2d.), 45 cents in U.S.A.

### Electrostatic Induction between Power Lines and Telephone Lines

By H. R. J. KLEWE, D.Phil. E.R.A. Technical Report L.M/T109. Pp. 25. Price 12s. (post 3d.).

The British & Allied Industries Research Associations, Thorncroft Manor, Dorking Road, Leatherhead, Surrey.

### The Elliott Journal

This new journal is expected to appear at about six-monthly intervals and is intended as a "review of developments in engineering and physical science with particular reference to the work of Elliott Brothers (London), Ltd." Copies are available on request from this firm at Century Works, Lewisham, London, S.E.13.

## P.O. ENGINEER-IN-CHIEF

Sir Archibald Gill, the present Engineer-in-Chief, General Post Office, is retiring on 1st October 1951, and will be succeeded by the present Deputy Engineer-in Chief, Dr. W. G. Radley, C.B.E., Ph.D.

Dr. Radley entered the Post Office Engineering Department in 1920. He became Controller of Research in 1944 and has been engaged on many aspects of research work, including magnetic and dielectric properties of materials, interference between power and telephone lines, and the development of long-distance signalling and dialling. He was appointed Deputy Engineer-in-Chief in 1949.

## ERRATUM

In referring to m.k.s. units on p. 258 of the August issue, the permittivity of free space was given as $\epsilon_o = 1\mu_o c$ F/m. It should, of course, have been $\epsilon_o = 1/\mu_o c^2$ F/m.

# CORRESPONDENCE

*Letters to the Editor on technical subjects are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.*

## Transmission Line Equivalent Circuit

SIR,—In teaching certain aspects of transmission line theory it is convenient to have, at times, an equivalent RLC circuit which will simulate a quarter-wave, short-circuited line over a narrow band of frequencies. Such a circuit is not only useful for certain calculations but it also aids the student to visualize the conditions on the line at frequencies close to resonance. The development is as follows:

Given a quarter-wave transmission line operating at a high frequency and short-circuited at the receiver end, it is required to find an equivalent parallel circuit of $R$, $L$, and $C$ which will simulate the input impedance at frequencies near resonance. It will be assumed that from 5% below to 5% above resonance, the value of $\alpha$ and of $Z_o$ will remain substantially constant.

If $S$ is the length of the line,

$$Z_s = Z_o \frac{\sinh(\alpha + j\beta)S}{\cosh(\alpha + j\beta)S}$$

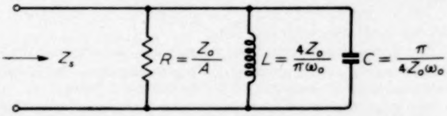
$$= Z_o \frac{\sinh \alpha S \cos \beta S + j \cosh \alpha S \sin \beta S}{\cosh \alpha S \cos \beta S + j \sinh \alpha S \sin \beta S} \quad .. \quad (1)$$

where $S = c/4f_o = \pi c/2\omega_o$, and $\beta = \omega/c$.

Accordingly, $\alpha S = \alpha\pi c/2\omega_o$, a constant, and $\beta S = \frac{\omega}{c}\frac{\pi}{2}\frac{c}{\omega_o} = \frac{\pi}{2}\frac{\omega}{\omega_o}$

That $\alpha S \ll 1$ can be seen as follows. Assuming $\alpha$ to be of the order of 0·01 neper/meter, and $\omega_o$ to be $4\pi \times 10^8$ radians/second, then

$$\alpha S = \frac{0{\cdot}01\pi \times 3 \times 10^8}{2(4\pi)10^8} = \frac{0{\cdot}03}{8} \approx 0{\cdot}004$$



$Z_s$
$R = \frac{Z_o}{A}$
$L = \frac{4Z_o}{\pi\omega_o}$
$C = \frac{\pi}{4Z_o\omega_o}$

On the other hand, $\beta S$ will be nearly $\pi/2$ radians if $\omega$ does not differ from $\omega_o$ by more than 5%. Hence, we can write

$$\sinh \alpha S \approx \frac{\alpha\pi c}{2\omega_o} = A$$

$$\cosh \alpha S \approx 1$$

$$\sin \beta S \approx 1$$

$$\cos \beta S \approx \sin\left(\frac{\pi}{2} - \beta S\right) \approx \frac{\pi}{2} - \beta S$$

$$= \frac{\pi}{2} - \frac{\pi}{2}\frac{\omega}{\omega_o} = \frac{\pi}{2}\frac{\omega_o - \omega}{\omega_o} = \frac{\pi}{2}\frac{\Delta\omega}{\omega_o}$$

and equation (1) becomes

$$Z_s = Z_o \frac{A\frac{\pi}{2}\frac{\Delta\omega}{\omega_o} + j}{\frac{\pi}{2}\frac{\Delta\omega}{\omega_o} + jA} = Z_o \frac{Ax + j}{x + jA} \quad .. \quad .. \quad (2)$$

where $x = \frac{\pi}{2}\frac{\Delta\omega}{\omega_o}$, and is restricted to values such that

$$-0{\cdot}0785 \leqslant x \leqslant 0{\cdot}0785.$$

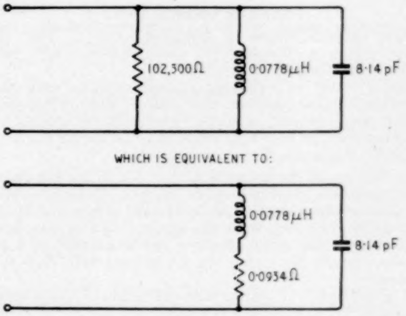
The impedance $Z_s$ given by equation (2) must be equivalent to some parallel-resonant circuit such as shown in Fig. 1, at frequencies near resonance. Thus

$$\frac{1}{Z_s} = \frac{1}{R} + \frac{1}{j\omega L} + j\omega C = \frac{x + jA}{Ax + j}\frac{1}{Z_o}$$

$$= \frac{1}{Z_o}\left[\frac{Ax^2 + A}{A^2x^2 + 1} + j\frac{A^2x - x}{A^2x^2 + 1}\right] \quad .. \quad .. \quad (3)$$

and $$R = Z_o \frac{A^2x^2 + 1}{A(x^2 + 1)} \quad .. \quad .. \quad .. \quad .. \quad (4)$$

Since $x^2 \ll 1$, and $A^2 \ll 1$, $R \approx \frac{Z_o}{A}$. $\quad .. \quad .. \quad (5)$



From equation (3),

$$\frac{Z_o}{j\omega L} + j\omega C Z_o = j\frac{A^2x - x}{A^2x^2 + 1}$$

which can be written

$$\omega C Z_o - \frac{Z_o}{\omega L} = \frac{A^2x - x}{A^2x^2 + 1} \approx -x = -\frac{\pi}{2}\frac{\Delta\omega}{\omega_o} \quad .. \quad (6)$$

The left side of this equation can be transformed into

$$\frac{Z_o}{\omega L}\frac{(\omega - \omega_o)(\omega + \omega_o)}{\omega_o^2} \approx -\frac{2Z_o}{L}\frac{\Delta\omega}{\omega_o^2}$$

Therefore,

$$-\frac{\pi}{2}\frac{\Delta\omega}{\omega_o} \approx -\frac{2Z_o\Delta\omega}{L\omega_o^2}$$

and $$L \approx \frac{4Z_o}{\pi\omega_o} \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (7)$$

Since $$C = \frac{1}{\omega_o^2 L}, \; C \approx \frac{\pi}{4\omega_o Z_o} \quad .. \quad .. \quad .. \quad (8)$$

The 'Q' of a parallel circuit is $R/L\omega_o$, so that, in this case,

$$Q = \frac{Z_o}{A}\frac{\pi}{4Z_o} = \frac{1}{2}\frac{\omega_o}{c}\frac{1}{\alpha} = \frac{\beta}{2\alpha} \quad .. \quad .. \quad .. \quad (9)$$

agreeing with the usual expression for the 'Q' of a transmission line.

A circuit made up of elements as shown in Fig. 1 should act as the actual line over a narrow frequency band near resonance. Let a coaxial cable be selected which has the following constants at $2 \times 10^8$ c/s.

$$\alpha = 0{\cdot}002 \text{ nep/m}, \ \beta = 4{\cdot}19 \text{ rad/m}, \ Z_o = 76{\cdot}8 \text{ ohms.}$$

Then
$$Q = \frac{\beta}{2\alpha} = \frac{4{\cdot}19}{2(0{\cdot}002)} = 1048$$

$$A = \frac{\alpha\pi c}{2\omega_o} = 0{\cdot}00075$$

and
$$R = \frac{Z_o}{A} = 102{,}300 \text{ ohms.}$$

From equations (7) and (8)

$$L = 7{\cdot}78 \times 10^{-8} \text{ H}$$

and
$$C = 8{\cdot}14 \times 10^{-12} \text{ F.}$$

The equivalent parallel circuit now becomes as shown in Fig. 2.

L. A. Ware.

State University of Iowa,
Iowa City, U.S.A.
22nd May, 1951.

## Television Camera Tubes

Sir,—Messrs. White & McGee's letter in your May issue raises a number of criticisms on my paper "Television Camera Tubes."*

As a result of extended correspondence with these authors it would appear that one of their criticisms is valid, one is invalid, and the remainder are questions of viewpoint. The following notes may be useful in clarifying the situation:—

1. My use of the formula $\delta\overline{I_n^2} = 2eI_a\delta f$ for the case of a temperature saturated space current, concerning which I was severely taken to task by Messrs. White and McGee, was perfectly valid, since the symbol $I_a$ was specifically stated to mean 'noise-effective anode current'; i.e., the anode current multiplied by an appropriate smoothing factor.

I must, however, accept some criticism of the notation, although I can hardly believe that my use of the symbol $I_a$ could cause any confusion except in the case of a 'blind' application of the formula. In the sequel I replace this symbol by $I_e$.

2. It is suggested that my 'sensitivity figure of merit' should be adjusted to include other tube properties, in particular signal/noise ratio. I consider that this procedure would be to over-stretch the significance of the term. There are many other tube properties which might be considered in setting up an 'overall figure of merit', but as it would be difficult to find a quantitative basis for this I have not attempted it. My 'sensitivity figure of merit' is intended to express only sensitivity, and this in terms of a practical operational light requirement; viz., the lighting at which an operating team arrives by extended experience in an endeavour to get the best operational results.

3. The above basis of light rating may account for the difference in sensitivity figures for the CPS Emitron as quoted by McGee and by myself. The table (below) for various camera tubes brings the information up to date at the present time.

4. I refer finally to the valid criticism that in my attempt to relate the behaviour of practical tubes to that of the ideal 'Quanticon' my method of utilization of the factor $\eta_2$ (gain of image stage) was erroneous. The point which has emerged clearly from our correspondence is that I had omitted to consider the noise contribution arising from primary photo-current noise which is stored on the target in the form of a noise pattern. This consideration affects the theoretical parts of my paper as follows:—Table 2 requires re-consideration, lines 2, 3, 4 and 7 being affected. The general noise/signal formula (6) requires modification, and, unfortunately, complication.

In re-examining the noise/signal formula as modified by the noise-pattern contribution I have found it necessary to distinguish between two classes of tube, the landed-beam-signal type as typified by the Orthicon and the return-beam-signal type as typified by the Image Orthicon. Also it is necessary to consider the difference of noise behaviour as between white, black, or intermediate tone values in the picture. Formula (6) becomes modified as follows:—For the landed-beam-signal type noise/signal ratio is:—

$$F^{\frac{1}{2}}I^{-1}[2eI\beta(1+\eta_2) + m^{-2}\{4kTR_1^{-1} + 2eI_e g^{-2}(R_1^{-2} + \tfrac{1}{3}(2\pi FC_1)^2)\}]^{\frac{1}{2}} \quad \ldots \quad \ldots \quad \ldots \quad (6a)$$

For the return-beam-signal type noise/signal ratio is

$$F^{\frac{1}{2}}I^{-1}[2eI(S_1 - \beta + \beta\eta_2) + m^{-2}\{\qquad\}]^{\frac{1}{2}} \quad \ldots \quad \ldots \quad (6b)$$

Here $I = \eta_2 I_1$; viz., the white photo-current times the image multiplication factor, $\beta$ is the relative brightness of the picture point referred to peak white and $I_e$ is the noise effective anode current of the head-amplifier valve.

These formulae are slightly academic in that the following assumptions are involved:—

(a) That the fluctuation of current associated with beam current $I_b$ is $\sqrt{2eFI_b}$; (White suggests the possibility of a smoothing factor being required here).

(b) That the fluctuation currents associated with the landed beam current $I_l$ and return beam current $I_r$ are $\sqrt{2eFI_e}$ and $\sqrt{2eFI_r}$ respectively; i.e., that the selective process of the landing mechanism does not affect the fluctuations to be associated with these two currents.

(c) That the electron multiplication process is noiseless *per se*.

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* "Television Camera Tubes," *Wireless Engineer*, January 1951.

**TABLE**

| Tube | Photo-cathode area (cm²). | Operating Conditions* | | | $\phi$ (lumens) | $\phi^{-\frac{1}{2}}$ | $\phi^{-\frac{1}{2}}/\phi_q^{-\frac{1}{2}}$ |
|---|---|---|---|---|---|---|---|
| | | $E$ (lux) | $N$ | $T$ | | | |
| Image Orthicon 5826 .. | 7·75 | 500 | 8-11 | 1 | $7{\cdot}6 \times 10^{-4}$ | 36 | 0·176 |
| Image Orthicon 5820 .. | 7·75 | 500 | 11-16 | 1 | $4{\cdot}0 \times 10^{-4}$ | 50 | 0·245 |
| CPS Emitron .. .. | 15·3 | 750 | 6·3-8·0 | 0·5 | $18 \times 10^{-4}$ | 24 | 0·118 |
| "Midget Super" Emitron .. | 1·8 | 750 | 2·8 | 1 | $22 \times 10^{-4}$ | 21 | 0·103 |

* These operating conditions correspond to the conservative rating of par. (2). Both Image Orthicons and CPS Emitrons have much higher ultimate sensitivities.

When further data is available on the above three points the formulae can be further modified appropriately.

L. H. Bedford.

Marconi's Wireless Telegraph Co., Ltd.,
Chelmsford, Essex.
13th July, 1951.

Sir,—As Mr. Bedford mentions in his letter (above), we have had some correspondence with him on the points raised in our letter published in your May issue. Although, as a result, the differences between us have narrowed, we are not as fully in accord as might be understood from his present letter, and we should like to make our position clear.

In the first place, we wish to apologize to him for failing to notice his qualification 'noise effective' in defining $I_a$ on p. 15 of the paper. He now proposes to use $I_e$ to distinguish the noise-effective current from the full anode current $I_a$. This is helpful, but we feel that $kI_a$ would be better. In practice $k$ has a value of about 0·15.

With the premises stated, we agree with the analysis of the internal mechanism of low-velocity pick-up tubes as outlined above by Mr. Bedford, following our pointing out the fundamental importance of the random fluctuations in the primary photo-emission. His revised figures given above for normal working conditions for good quality pictures are agreed. For the CPS Emitron they are not substantially different from information available at the reading of our I.E.E. papers in April 1950.

We cannot, however, agree with Mr. Bedford's remarks above, that sensitivity has any meaning unless signal/noise ratio is specified. This, to our mind, scarcely needs arguing at this date. There can, of course, be difference of opinion as to the value of signal/noise ratio to take as a standard, but we did not dispute Mr. Bedford's adoption of 40 db (for the 'Quanticon') for the case of noise having a flat frequency spectrum.

This leads to the important point that in all existing types of tube there is an upper limit to the obtainable signal/noise ratio even with no limitation of light. This is determined largely by the capacitance of the target, and the maximum allowable potential change of target elements. This limitation is not specifically introduced into the above analysis, but its effect can be seen since it sets a limit to the useful target-charging current $I$. Thus it will be noticed from equation (6b) above that for constant $I$ the noise increases with increase of $\eta_3$, so that image multiplication is not necessarily desirable. Image multiplication occurs in the Image Orthicon, but not in the CPS Emitron, which also has the higher target capacitance.

Our criticisms of Section 4 of the paper seem to be tacitly agreed to by Mr. Bedford.

J. D. McGee.
E. L. C. White.

E.M.I. Research Laboratories, Ltd.,
Hayes, Middlesex.
17th July, 1951.

# NEW BOOKS

## Electromagnetic Waves and Radiating Systems

By E. C. Jordan. Pp. 710+x. Constable & Co., Ltd., 10 Orange Street, London, W.C.2. Price 32s. 6d.

The author is Professor of Electrical Engineering at the University of Illinois; the book is printed in the U.S.A. and is one of the Prentice-Hall Electrical Engineering Series, of which Professor Everitt of Ohio University acts as editor. It is intended as a text-book for final-year University and post-graduate students, and is very comprehensive. In the first chapter entitled "Fundamentals of Electromagnetic Engineering," the student is given a good grounding in vector algebra, units and dimensions. The rationalized m.k.s. system is used. The term displacement is applied to the total quantity across any surface; the quantity per unit area is called the displacement density, and the unit is the coulomb per square metre. Chapters 2 and 3 deal with electrostatics and the steady magnetic field; the treatment is very clear, approximations being explained in dealing with practical problems. The much-debated question as to the analogies between the electric and magnetic fields is discussed. Maxwell's equations are developed in Chapter 4; Kirchoff on p. 97 should be Kirchhoff, and Stoke on p. 101 should be Stokes. Chapter 5 is devoted to electromagnetic waves, depth of penetration, reflection, Brewster angle, etc., and Chapter 6 to the Poynting vector and the flow of power. Chapter 7 deals with guided waves and Chapter 9 with waveguides, the chapter between them dealing with ordinary transmission lines. Chapters 10 and 11 are devoted to radiation from aerials and the calculation of the impedance; the latter subject is treated very fully, 48 pages being devoted to it. Chapters 12 and 13 cover the directional and impedance characteristics of aerials, Chapter 14 with aerial practice and design, and Chapter 15 with secondary sources and aperture aerials. The two final chapters are devoted to ground-wave and sky-wave propagation. Appendix 1 explains group and phase velocities and Appendix 2 gives a brief review of Bessel Functions. Every chapter concludes with a number of problems and a bibliography. Although in the chapter on sky-wave propagation there is a discussion of the E and F layers in the ionosphere, the name of Appleton is not mentioned and does not figure in the index. The name Pisolkors which occurs in text and index should surely be Pistolkors, and Janke and Emde should be Jahnke and Emde. These are, however, just careless details and detract little from the value of the book, which is an admirable text-book that can be recommended to anyone wishing to obtain a thorough grounding in the fundamentals of the subject.

G. W. O. H.

## Radio Installations

By W. E. Pannett. Pp. 444 with 244 illustrations. Chapman & Hall, Ltd., 37 Essex Street, London, W.C.2. Price 45s.

This book is concerned with the practical design, construction and maintenance of modern radio transmitting and receiving installations for broadcasting and commercial communications purposes.

It is written by an engineer who has devoted some 30 years to this type of work and who is well qualified to write on the subject. The book should prove of great value to the engineer whose work is concerned with the overall planning of radio stations and the installing engineer who is called upon to erect, put into service and maintain these stations and has to deal with a wide range of radio and power equipment with little specialist assistance.

In his foreword, G. M. Wright, the Chief Engineer of Marconi's Wireless Telegraph Co., Ltd., rightly states that this book is "unique in the extensive literature devoted to radio communication." This lies in the fact that the author steadfastly refuses to become more technical than he need be, always emphasises the practical issues which he feels the installation engineer requires to know and because much of the information he gives is of the type which is rarely available except in the engineering departments of a long-established radio-manufacturing organization or a broadcasting authority. The book is not a text book in the usually accepted sense of the word but an attempt to put on record the results of applied radio-engineering experience of the sort which is tending to become lost amid the welter of present-day specialized applications.

The scope of the book is very wide and assumes that the reader is acquainted with basic electrical power and radio theory. There are 16 chapters, and the author deals with everything from the factors concerned in the initial choice of the transmitting or receiving site to the routine maintenance and testing of completed installations. Within these chapters are sections devoted to the station building, foundations, equipment layouts, power cabling, power supply and distribution switchgear and the characteristics of specialized power supplies for valves, including filament heating and high-voltage anode-supply plant. High-voltage rectifier equipments and their smoothing filters for high-power installations are well considered.

On the radio-frequency side, the book deals with the types and characteristics of amplifiers and oscillators, together with the basic overall design and construction of complete transmitters, including modulating and keying systems, air and water valve-cooling systems, and control and protection equipment. This is followed by chapters outlining the characteristics and practical construction of radio-frequency transmission lines, methods of line switching, impedance matching and aerial-coupling circuits. The two penultimate chapters are devoted to communication receiving equipment and the equipment of radio-control centres for radio telephone and telegraph traffic. The final chapter is concerned with transmitting and receiving station maintenance, testing and test equipment.

The book is not one for the specialist because the author has of necessity had to be very general in order to deal with the wide range of equipment he describes. It is, however, recommended for the practical installation engineer and station operator to whom it is specifically directed. It is well produced with good type and the diagrams and curves are clear and well conceived.

P. A. T. B.

### Die wissenschaftlichen Grundlagen der Elektrotechnik.

By Heinz Schönfeld. Pp. 258 + xi, with 296 illustrations. S. Hirzel Verlag, Goethestrasse 2, Leipzig, C.1.

Dr. Schönfeld is Professor and Director of the Institute for General Electrotechnics in the Technische Hochschule at Dresden, and the object of this book is to lay scientific foundations of electrotechnics on a broad basis. As the author says, there are many such books but he considers his to be justified because of its contents and method of presentation. Of the four chapters, the first deals with electrical phenomena in conductors, the second in non-conductors, the third with electromagnetic phenomena, and the fourth is a general review of the whole, with special reference to alternating currents. The author thanks Professors Barkhausen and Feldtkeller for their help and co-operation.

The author does not hesitate to depart from standard usage if he thinks it desirable. The term "electromotive force" does not occur in the book, except in a footnote explaining that, as it is not really a force, the author has replaced it by "Urspannung", which might be translated "originating tension". Instead of putting $n$ for revolutions per minute he writes $n/1/\text{min}$, the $1/\text{min}$ indicating the unit in which $n$ is measured, viz, one per minute. Similarly the formula $B/_{G} = 1{\cdot}256\mu_{\mathrm{rel}}\, H \Big/ \frac{\mathrm{A}}{\mathrm{cm}}$ indicates that the unit of $B$ is the gauss and the unit of $H$ an ampere per cm. The formula $P/_{\mathrm{kp}} = 1{\cdot}02,\ 10^{-7} J/_{\mathrm{A}}.B/_{\mathrm{G}}.l/\mathrm{cm}$ indicates that the force $P$ on the current-carrying conductor is given in kiloponds, the pond being a new name for the weight of a gram.

With regard to units there appears to be no mention of Giorgi or the m.k.s. system and the author says that because of the numberless possibilities of confusion, he avoids the use of the c.g.s. system. The system adopted appears to be the rationalized practical system of electromagnetic units combined with the c.g.s. mechanical system; for example, the formula given for the permeability of space is $\mu_0 = 0{\cdot}4\pi.10^{-8}\mathrm{H/cm}$. Although resistance is given as the reciprocal of conductance, this does not apply to specific resistance and specific conductance, due to the fact that the former is given for a length of 1 metre and a cross-section of 1 mm$^2$ whereas the latter is given for a cm cube. A strange looking word that often occurs is "Trafo"; this apparently bears the same relation to a transformer as a "galvo" does to a galvanometer.

Practical applications are a feature of the book, the construction and principles of such things as measuring instruments of various types, capacitors, dynamos, motors, 3-phase networks, etc., being described with suitable diagrams.

Each chapter concludes with some exercises, forty-eight in all, the solutions of which are given in an appendix.

Inserted in the book is a notice advertising a series of four educational letters each of 60 pages, which may be regarded as appendices to the book, describing things in greater detail and answering questions that are likely to be asked by students reading the book. They are intended for distant students and may be regarded as a correspondence course based on the book.

G. W. O. H.

### Television Explained (4th Edition)

By W. E. Miller, M.A. (Cantab.), M.Brit.I.R.E. Pp. 104 with 75 illustrations. Trader Publishing Co., Ltd., distributed by Iliffe & Sons, Ltd., Dorset House, Stamford St., London, S.E.1. Price 5s. (postage 4d.).

### Radio Valve Data (2nd Edition)

Pp. 80. Published for *Wireless World* by Iliffe & Sons, Ltd., Dorset House, Stamford St., London, S.E.1. Price 3s. 6d. (postage 4d.).

Contains characteristics of 2,000 British and American valves and 100 cathode-ray tubes. Data is presented in tabular form and includes valve-base connections.

### The Microphysical World

By William Wilson, Ph.D., D.Sc., F.R.S. Pp. 216 + vii. Methuen & Co., Ltd., 36 Essex St., London, W.C.2. Price 5s.

### Electronics

By P. Parker, M.Sc., A.Inst.P., A.M.I.E.E. Pp. 1050 + viii. Edward Arnold & Co., 41 Maddon St., London, W.1. Price 50s.

### Traveling-Wave Tubes

By J. R. Pierce. Pp. 260 + xi. (Bell Laboratory Series), Macmillan & Co., Ltd., St. Martins Street, London, W.C.2. Price 34s.

# ABSTRACTS and REFERENCES

**Compiled by the Radio Research Organization of the Department of Scientific and Industrial Research and published by arrangement with that Department.**

*The abstracts are classified in accordance with the Universal Decimal Classification. They are arranged within broad subject sections in the order of the U.D.C. numbers, except that notices of book reviews are placed at the ends of the sections. U.D.C. numbers marked with a dagger (†) must be regarded as provisional. The abbreviations of the titles of journals are taken from the World List of Scientific Periodicals. Titles that do not appear in this List are abbreviated in a style conforming to it.*

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## ACOUSTICS AND AUDIO FREQUENCIES

534 + 621.395 **2082**

**1951 I.R.E. National Convention Program.**—(*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 292–315.) Summaries are given of the following papers:—

167. A Single-Ended Push-Pull Audio Amplifier.—A. Peterson & D. B. Sinclair.
168. The Application of Damping to Phonograph Reproducer Arms.—W. S. Bachman.
169. Transient Testing of Loudspeakers.—O. K. Mawardi.
195. Amplitude and Phase Measurements on Loudspeaker Cones.—M. Corrington.
196. Design Elements for Improved Bass Response in Loudspeaker Systems.—H. T. Souther.
197. Direct Radiator Loudspeaker Mounting.—H. F. Olson.
198. Physical and Electrical Constants of Direct Radiator Loudspeakers.—L. L. Beranek.

534-14 **2083**

**The Sonic Scattering Layer in the Sea.**—A. C. Burd & A. J. Lee. (*Nature, Lond.*, 21st April 1951, Vol. 167, No. 4251, pp. 624–626.) A report of observations of variable scattering layers in seas near Great Britain. No general explanation of their origin can be given, but some layers are most probably due to small marine organisms, others to shoals of young fish.

534.22-14 : 534.321.9 **2084**

**A Method of Measuring the Velocity of Propagation of Ultrasonic Waves in Fluids.**—T. S. Velichkina & I. L. Fabelinski. (*C. R. Acad. Sci. U.R.S.S.*, 11th Nov. 1950, Vol. 75, No. 2, pp. 177–180. In Russian.) The method is based on the production of interference by transmission through a stratified medium; the principle has previously been used for determining the velocity of sound in solids.

534.232 **2085**

**An Electromechanical Source of Elastic Waves in the Ground.**—F. F. Evison. (*Proc. phys. Soc.*, 1st April 1951, Vol. 64, No. 376B, pp. 311–322.) A large moving-coil transducer is described which, when attached rigidly to rock, radiates sinusoidal vibrations of controllable amplitude, frequency and duration. Its operation is analysed by the method of electromechanical analogy. Measurements made in a chalk mine are reported: 20-ms square pulses of 300-, 600- and 1 000-c/s energy were radiated, the power being about 0·05 W. The detecting system included a piezoelectric microphone and oscillograph, with an overall magnification of about $10^9$.

534.321.7.08 : 621.317.755 **2086**

**Precise Calibration of Tuning Forks.**—Addink. (See 2234.)

534.373 : 534.414 **2087**

**The Damping of Acoustic Resonators.**—K. Voelz. (*Z. angew. Phys.*, Feb. 1951, Vol. 3, No. 2, pp. 67–72.) The damping is investigated for the general case where the compressional viscosity of the resonating medium is not necessarily equal to zero. The two terms due respectively to the internal friction of the medium and the boundary friction are calculated for a resonator of arbitrary form. When applied to cylindrical and spherical resonators, the results obtained agree with the formulae of Kirchhoff and Lamb. The influence of thermal conductivity is discussed.

534.62 **2088**

**Anechoic Chamber for Acoustic Measurements.**—D. W. Robinson. (*Elect. Commun.*, March 1951, Vol. 28, No. 1, pp. 70–77.) The room was constructed in accordance with fundamental designs outlined by Beranek & Sleeper (3529 of 1946), and uses fibreglass wedges as the main sound-absorbing material. Results of performance tests are given.

534.85 **2089**

**Thorn Needles.**—A. M. Pollock. (*Wireless World*, April 1951, Vol. 57, No. 4, pp. 145–146.) Further discussion, including description of the method of sharpening. See also 1831 of August (Watts : Kelly).

534.862.4 : 534.861.3 : 534.421 **2090**

**Bass without Big Baffles.**—K. A. Exley. (*Wireless World*, April 1951, Vol. 57, No. 4, pp. 132–134.) Description of a method of increasing the content of harmonics of the lower bass frequencies by introducing harmonics from a second channel in which amplitude distortion has been allowed to occur.

621.395.62 : 621.395.667 **2091**

**A Continuously Variable Equalizer.**—Fling. (See 2129.)

621.395.623.7 : 537.52 **2092**

**Variations of Discharge Parameters in Preliminary Discharges, and Measurement of Variations.**—Fucks. (See 2143.)

621.395.623.73 **2093**

**Proposal for the Quality Rating of Dynamic Cone Loudspeakers.**—E. Hüttmann. (*Elektrotechnik, Berlin*, March 1951, Vol. 5, No. 3, pp. 128–132.) It is suggested that assessment of the quality of loudspeakers should be based on definite characteristic physical data and that it should be possible to determine the necessary data by relatively simple methods. The principal characteristics of cone loudspeakers are discussed and measurement methods are outlined and applied to a typical loudspeaker.

621.395.625.3 **2094**

**New Professional Tape Recorder.**—W. E. Stewart. (*Audio Engng*, April 1951, Vol. 35, No. 4, pp. 21–23 . . 37.) A detailed description of the design and construction of R.C.A. Type-RT-11A equipment. Remote control, involving relay and solenoid operation of all functions, is provided; a safety switch stops the machine automatically in case of tape breakage. Design of the recording and reproducing amplifiers is indicated by schematic diagrams and follows conventional practice, frequency compensation by inverse feedback is provided in both circuits and precautions are taken to reduce hum.

621.396.645.029.4 **2095**

**A 15-Watt Direct-Coupled Amplifier.**—Fraser. (See 2134.)

534.321.9 **2096**

**Ultrasonics.** [Book Review]—P. Vigoureux. Publishers: Chapman & Hall, London, 1950, 163 pp., 25s. (*Phil. Mag.*, April 1951, Vol. 42, No. 327, p. 439.) "The author has dealt with the technique and with the theory of ultrasonics in simple terms which bring the work within the scope of a wide circle of readers including undergraduates."

## AERIALS AND TRANSMISSION LINES

621.392.09 **2097**

**Surface-Wave Propagation over a Coated Plane Conductor.**—S. S. Attwood. (*J. appl. Phys.*, April 1951, Vol. 22, No. 4, pp. 504–509.) Propagation of the type described by Goubau (281 of February and 812 of April) is discussed, the case of the plane conductor being chosen to simplify calculations. "Basic equations are developed for both dielectric layer and air regions, which indicate a criss-cross or multiply reflected wave in the dielectric and a unidirectional wave in the air. Equations are developed also for the electric flux line shapes, power propagated over the cross-section, concentration of power flow in neighborhood of the film, attenuation due to conductor wall loss and dielectric film loss. Numerical calculations are given for five film thicknesses varying from 0·0001 to 0·01 meter and for five frequencies ranging from $3\times10^8$ to $3\times10^{10}$ cycles per second."

621.392.09 **2098**

**Propagation on Dielectric Coated Wires.**—E. T. Kornhauser. (*J. appl. Phys.*, April 1951, Vol. 22, No. 4, p. 525.) Comment on work noted in 812 of April (Goubau).

621.392.2 : 621.396.611.39 **2099**

**Approximate Theory of the Directional Coupler.**—F. Bolinder. (*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, p. 291.) The construction is discussed of directional couplers providing the optimum relation between the width of the pass band and the pass-band level of the reverse wave $I_{rev}$ in the coupled line. Curves are given for an 8-element directional coupler with a tolerance of 5% in the value of $I_{rev}/I_{max}$ in the pass band, and for two directional couplers consisting of continuous slots of varying width. Mumford's assumptions (2007 of 1947) are considered valid. See also 562 of March.

621.392.26† + 621.396.67 **2100**

**1951 I.R.E. National Convention Program.**—(*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 292–315.) Summaries are given of the following papers:

12. The Design and Use of the Automatic Antenna Pattern Recorder.—J. W. Tiley.
13. Stagger-Tuned Loop Antennas for Wide-Band Low-Frequency Reception.—D. K. Cheng & R. A. Galbraith.
14. Theory of the Concentric-Slot Antenna.—T. Morita.
15. Optimum Current Distributions for Antenna Arrays with Circular Symmetry.—R. H. DuHamel.
16. Directional Antenna Arrays of Elements Circularly Disposed about a Cylindrical Reflector.—R. F. Harrington & W. R. LePage.
54. Performance of Sectionalized Broadcasting Towers.—C. E. Smith.
73. Development of Waveguide Switches for Commercial and Military Applications. — T. N. Anderson.
74. Low-Loss Waveguide Transmission.—S. E. Miller & A. C. Beck.
75. Dominant Wave Transmission Characteristics of a Multimode Round Waveguide.—A. P. King.
76. Radial Probe Measurements of Mode Conversion in Large Round Waveguide with $TE_{01}$ Mode Excitation.—M. Aronoff.
77. A Broadband Microwave Quarter-Wave Plate.—A. J. Simmons.
78. The Precision Measurement of the Equivalent Circuit Parameters of Dissipative Microwave Structures.—A. A. Oliner & H. Kurss.
102. On the Excitation of Surface Waves.—G. Goubau.
103. Interaction between Surface Wave Transmission Lines.—A. A. Meyerhoff.
104. A New Directional Coupler permitting Full Power Transfer.—K. Tomiyasu & S. B. Cohn.
105. Multi-Element Directional Couplers.—S. E. Miller & W. W. Mumford.
106. The Effect of Radiation on the $Q$ of Resonant Sections of Unshielded Parallel-Wire Transmission Line.—R. A. Chipman, E. F. Carr & N. A. Hoy.
124. Single-Tapped Coil Delay Line.—S. G. Lutz.
125. Nickel Acoustic Delay Line.—T. F. Rogers & S. J. Johnson.
132. The Study of Artificial Dielectrics of the Obstacle Type.—C. Susskind.
133. Isotropic Artificial Dielectric.—R. W. Corkum.
134. A Virtual Source in Microwave Optics.—K. S. Kelleher.
135. Experimental Prototype of the Rinehart-Luneberg Lens.—E. C. Fine.
136. Propagation of Microwaves between Parallel Conducting Surfaces.—K. S. Kunz.
137. Phase Shift of Microwaves in Passage through Parallel-Plate Arrays.—D. J. Epstein.
162. The Half Space as a Spherical Transmission Line.—L. Felsen & N. Marcuvitz.
163. The Calculation of Progressive-Phase Shaped Beam Antennas.—A. S. Dunbar.
164. Physical Limitations on Minimum Side Lobes in Broadside Arrays.—J. Ruze.
165. The Behavior of Microwaves in Focal Regions.—F. J. Zucker.
166. A Microwave Schmidt System.—H. N. Chait.

621.392.26† **2101**

**Analysis of Symmetrical Waveguide Junctions.**—D. M. Kerns. (*Bur. Stand. J. Res.*, April 1951, Vol. 46, No. 4, pp. 267–282.) "An arbitrary electric (or magnetic) field in a waveguide junction is expressible linearly in terms of a finite number of linearly independent electric (or magnetic) basis fields. From any given ordered pair of electric (or magnetic) basis fields one can in principle calculate a complex number—an element of the admittance (or impedance) matrix characterizing the junction (relative to the choice of basis fields). The geometric concept of rotation and reflection of fields (and structures) is discussed in terms of a rotation-reflection operator, and the symmetry of a junction is characterized by a group of rotation-reflection operations under which the structure is invariant. A general procedure is given for the construction of a basis in which the basis fields transform according to irreducible representations of the symmetry group involved."

621.392.26† **2102**

**Diffractive Apertures in Waveguides.**—M. Jessel. (*C. R. Acad. Sci., Paris*, 23rd April 1951, Vol. 232, No. 17, pp. 1546–1548.) The propagation of waves in rectangular waveguides with rectangular or polygonal apertures was studied. At a frequency permitting only one mode of propagation, the section containing the aperture can be regarded as a quadripole. The relations between reflected and transmitted components of the wave are expressed in matrix form. Satisfactory agreement is found between calculated and measured values of the transmitted component in two special cases, at wavelengths in the neighbourhood of 3 cm.

621.392.26† + 621.396.67] : 517.944 **2103**

**Separation of Variables in Electromagnetic Theory.**—D. E. Spencer. (*J. appl. Phys.*, April 1951, Vol. 22, No. 4, pp. 386–389.) Separability conditions are obtained for the partial differential equations of electromagnetic theory. Problems of waveguides and aerials are expressed in terms of the vector Helmholtz equation, and solutions are indicated by use of the simple method of separation of variables without recourse to Green's functions.

621.392.26† : 621.392.52 **2104**

**Waveguide Filters for Pulse Transmission Studies.**—P. A. Reiling. (*Bell Lab. Rec.*, April 1951, Vol. 29, No. 4, pp. 164–168.) Describes channel-separation filters for a multichannel microwave waveguide system. Two waveguides carrying identical groups of four frequencies feed into opposite ends of a square waveguide, diagonal polarization being used. Four filter units arranged at intervals along the guide reflect the four frequencies respectively, with rotation of the polarization through 90°. Hybrid units consisting of rectangular guides mounted on the edges of the square guide, together with metal sheets placed diagonally across the square guide, divert the reflected waves into amplifiers. A similar system combines the waves after amplification. See also 294 of 1949 (Lewis).

621.392.26† : 621.396.67 **2105**

**Properties of Longitudinal Slots in Circular Waveguides.**—C. E. Feiker & S. C. Clark, Jr. (*Tele-Tech*, March 1951, Vol. 10, No. 3, pp. 42–44, 82.) Measurements of slot admittance indicate properties similar to those of slots in the broad faces of rectangular waveguides. Tables and diagrams present experimental results of admittance measurements, radiation patterns and power breakdown characteristics for narrow and wide slots.

621.392.5 **2106**

**Calculating Transmission-Line Load Impedance.**—S. G. Lutz. (*Elect. Engng, N.Y.*, Feb. 1951, Vol. 70, No. 2, p. 128.) Digest of A.I.E.E. 1951 Winter General Meeting paper. A discussion of some features of the transmission-line equations and their use for determining the load impedance giving greatest transmission efficiency. The characteristic impedance is not necessarily the optimum load.

621.392.5 : 538.652 **2107**

**Magnetostrictive Delay Line.**—E. M. Bradburd. (*Elect. Commun.*, March 1951, Vol. 28, No. 1, pp. 46–53.) A comparison of various signal-delay systems is presented. The magnetostrictive type provides a continuously adjustable delay and accommodates a multiplicity of pulses simultaneously. The fundamental design equations for this type are given, and methods for improving pulse response and eliminating undesired reflections at the ends of the line are described.

621.396.67 **2108**

**The Effect of a Grounded Slab on the Radiation from a Line Source.**—C. T. Tai. (*J. appl. Phys.*, April 1951, Vol. 22, No. 4, pp. 405–414.) A method of investigation based on Fourier transforms is used. The principal part of the electric field above the dielectric slab can be found either by evaluating the resultant contour integral, using the saddle-point method of integration, or by evaluating the integral containing the tangential $H$ field along the interface. The radiation pattern of the principal field is identical with the field resulting from a direct and a reflected ray, as derived from geometrical optics. When the slab is thick enough to support wave propagation, in addition to the space wave a surface wave appears in the neighbourhood of the interface; the latter attenuates rapidly as the distance from the interface increases. The deformation of the path of integration corresponding to different angles of observation is displayed graphically.

621.396.67 **2109**

**The Calculation of the Radiation from Ultra-Short-Wave Aerials.**—É. Divoire & J. Delcambe. (*HF, Brussels*, 1950, No. 8, pp. 201–214.) When the wavelength becomes less than the linear dimensions of the aerial, methods of calculating radiation based on Huyghens' principle have to be used, as in acoustics and optics. The modifications necessary in applying the standard theory to the case of radio waves are discussed, and formulae derived for the field at a distance from a radiating surface are shown to conform to Maxwell's equations and to be in good agreement with experiment.

621.396.671 **2110**

**Diffraction Errors in an Optical Measurement at Radio Wavelengths.**—G. A. Woonton, J. A. Carruthers, H. A. Elliott & E. C. Rigby. (*J. appl. Phys.*, April 1951, Vol. 22, No. 4, pp. 390–397.) Errors arising in the investigation of an aerial pattern by means of a lens are examined. The effect of the lens aperture is separated from that of lens aberrations, and only the former is discussed. A theoretical solution is obtained for a uniformly illuminated aperture in conjunction with short electromagnetic horns; agreement is found with measured results. Computed and measured results are used to investigate the mutilation of the pattern by the aperture. A lens 40 $\lambda$ wide can be used for precision measurements with aerials 10–20 $\lambda$ wide. The technique is useful for $\lambda \leqslant 3{\cdot}2$ cm.

621.396.679.4 : 621.315.212 **2111**

**Circular-Aperture and Slot Couplings between Coaxial Lines.**—H. Kaden. (*Z. angew. Phys.*, Feb. 1951, Vol. 3, No. 2, pp. 44–52.) Formulae are derived for designing circular-aperture and slot couplings, the discussion being restricted to cases in which the wavelength is large compared with the size of the aperture. For the circular aperture, both the capacitive and the inductive couplings are proportional to the cube of the aperture radius; for the slot, both couplings are proportional to the square of the slot width. The magnitudes of the two couplings are equal for the slot, but for the circular aperture the inductive coupling is twice as great as the capacitive coupling. When two aligned coaxial sections are separated by an apertured short-circuiting diaphragm, only inductive coupling is present, its magnitude being inversely proportional to the square of the distance of the aperture from the axis. The finite thickness of the diaphragm is taken into account. Applications to coaxial-line band-pass filters and directional couplers are described.

621.316.93 **2112**

**Protection of Transmission Systems against Lightning.** [Book Review]—W. W. Lewis. Publishers: Chapman & Hall, London, 418 pp., 64s. (*Elect. Times*, 1st March 1951, Vol. 119, No. 3095, p. 364.) "Five of the 11 chapters discuss basic details of lightning and of travelling waves. The rest of the book presents practical rules for minimizing the effects of lightning on transmission lines."

621.392.26† + 621.396.615.141/.142 **2113**

**Electromagnetic Problems of Microwave Theory.** [Book Review]—H. Motz. Publishers: Methuen & Co., London, 180 pp., 9s. 6d. (*Electrician*, 9th March 1951, Vol. 146, No. 3795, p. 824.) Theory of velocity modulation, klystrons, cavity magnetrons and waveguides is covered, the method of analysis being illustrated by thoroughly worked examples.

## CIRCUITS AND CIRCUIT ELEMENTS

621.314.12 : 621.314.3† **2114**

**A Simple Magnetic Modulator for Conversion of Millivolt D.C. Signals.**—G. Wennerberg. (*Elect. Engng, N.Y.*, Feb. 1951, Vol. 70, No. 2, pp. 144–147.) Modulation is achieved by a suitable arrangement of excitation (a.c.) and signal (d.c.) windings on two saturable cores. The output voltage is a stable sinusoidal signal of amplitude proportional to the d.c. signal level, and in phase or antiphase with the excitation voltage, depending upon the polarity of the d.c. input.

621.314.224 **2115**

**Double-Ratio Current Transformers.**—A. A. Halacsy. (*Elect. Times*, 22nd March 1951, Vol. 119, No. 3098, pp. 475–478.) In transformers with two equal sets of windings which can be connected either in series or in parallel to obtain different ratios, the actual ratios and phase angles obtained differ from the nominal values by amounts which are dependent on the particular combination used. Formulae are tabulated showing the errors for the various possible winding connections.

621.314.3† **2116**

**Some General Properties of Magnetic Amplifiers.**—J. M. Manley. (*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 242–251.) General discussion of the magnetic amplifier as a carrier system with a modulation gain and a small demodulation loss.

621.317.723 : 621.38 **2117**

**An Electrometer Impedance Convertor.**—E. J. Harris. (*Electronic Engng*, March 1951, Vol. 23, No. 277, pp. 109–110.) A circuit is described in which the input valve has extremely low grid current, and in which the electrometer stage derives its operating potentials from the cathode of the succeeding amplifier stage when injection from either the control grid or the suppressor grid is used. The circuit may be used to measure ionization currents, bioelectric potentials or hydrogen-ion concentrations.

621.318.42 **2118**

**Characteristic Impedance of Shielded Coils.**—C. Susskind. (*TV Engng, N.Y.*, March 1951, Vol. 2, No. 3, pp. 26–27, 31.) Measurements made on shielded coils of low-resistance wire and presented graphically demonstrate the dependence of characteristic impedance both on coil-to-shield spacing and on the ratio of coil diameter to shield diameter.

621.318.572 **2119**

**Transition of an Eccles-Jordan Circuit.**—J. R. Tillman. (*Wireless Engr*, April 1951, Vol. 28, No. 331, pp. 101–110.) A mathematical study of that part of the transition time occupied in charging the shunt capacitances of the circuit. An externally triggered system with two stable states is discussed. Transition takes place when the curve representing the gain of the closed loop containing the grids and anodes of the two valves encloses the point 1/0 on the Nyquist diagram. Analyses are made of valves with linear and parabolic characteristics, the calculated time-variation of anode potentials being shown graphically. A method of calculation by successive approximation is shown to give results in good agreement with analytical curves, provided sufficiently small steps are taken. Triggering is shown to be ineffective if the length of the pulse is too small, but the threshold value is often only a few millimicroseconds. The departures of the characteristics of practical circuits from those of the simple system analysed are discussed in some detail.

621.318.572 : 621.384.5 **2120**

**Ring Counter using Neon Lamps.**—L. N. Korablev. (*C. R. Acad. Sci. U.R.S.S.*, 21st Nov. 1950, Vol. 75, No. 3, pp. 375–378. In Russian.)

621.319.4 **2121**

**Styroflex Capacitors, their Properties and Application Possibilities.**—H. Geschka & F. Lange. (*Elektrotechnik, Berlin*, March 1951, Vol. 5, No. 3, pp. 133–137.) Methods are described for the production of capacitors from polystyrol ribbon and Al foil. Such capacitors have low losses, high breakdown voltage and a capacitance temperature coefficient of $-140 \times 10^{-6}$ per 1°C. Different available types are described. A comparative table shows the principal electrical and physical characteristics of capacitors with dielectric of styroflex, mica, and various titanate ceramics.

621.39 **2122**

**1951 I.R.E. National Convention Program.**—(*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 292–315.) Summaries are given of the following papers:

17. Calculations for Class-C Amplifiers with a Reactive Load.—D. A. Cawood.
33. The Servo-Modulator: a Low-Level D.C. Instrument.—G. M. Attura.
34. Transient Response of Self-Saturating Magnetic Amplifiers.—E. J. Smith.
35. Direct Current Amplifiers employing Magnettors.—E. P. Felch, V. E. Legg & F. G. Merrill.
36. Some Aspects of Magnetic Amplifier Technique.—R. Willheim & F. E. Butcher.
37. Drift Compensation in D.C. Amplifiers for Analogue Computers.—W. E. Ingerson.
38. Signal Flow Graphs.—S. J. Mason.
39. Some Biological Applications of Random Nets.—A. Rapoport.
41. Electric Network Models for Problems of Probability.—W. E. Bradley.
62. Network Synthesis applied to Feedback Control.—J. G. Truxal.
63. Network Synthesis by the Use of Potential Analogues.—R. E. Scott.

64. Transfer Ratio Synthesis by RC Networks.—J. T. Fleck & P. F. Ordung.
65. Electrical-Mechanical Equivalent Network Synthesis.—A. A. Gerlach.
66. Linear Network Neighborhood Equivalence.—D. R. Crosby.
67. Constant Resistance Varying-Parameter Networks.—L. A. Zadeh.
71. Generation of Sidebands due to Gain and Phase Shift Modulations in a Traveling Wave Tube Amplifier.—M. Arditi, A. G. Clavier & P. Parzen.
91. Time Domain Filters.—J. Snyder.
92. Pulse Reception Filters.—D. L. Waidelich.
93. Optimum Nonlinear Filters.—H. E. Singleton.
94. Nonlinear Sampling Filters.—W. D. White.
95. Statistical Filter Theory for Feedback Systems Subject to Saturation.—G. C. Newton, Jr.
96. Electronic Filter.—H. T. Sterling.
122. A Linear Operational Calculus of Empirical Functions.—R. G. Piety.
123. Pulse Transformer considered as a Wide-Band Network.—M. G. Rudenberg.
126. Amplifier Synthesis on Equal-Ripple Basis.—D. L. Trautman & J. A. Aseltine.
152. R.F. Amplifier Design for Low Noise Figure.—R. Guenther.
153. H.F. Amplifiers with Direct Coupling.—E. L. Crosby, Jr, & K. F. Umpleby.
154. Distributed Amplification: Additional Considerations.—J. Weber.
155. Distributed Amplification for Pulses.—G. F. Myers.
156. Cathode-Coupled Clipper Response. — P. F. Ordung & H. L. Krauss.
167. A Single-Ended Push-Pull Audio Amplifier.—A. Peterson & D. B. Sinclair.
180. Oscillator Frequency Indeterminancy. — L. Riebman.
181. Simultaneous Oscillations in Oscillators.—H. Schaffner.
182. Amplitude Stabilization of Oscillators by Nonlinear Networks. — L. Rosenthal.
183. Stability of Oscillations in a Nonlinear System.—N. R. Scott.
184. Tuned Coupled Circuit for Oscillator Application.—R. A. Martin & R. D. Teasdale.
191. 1 700- to 2 400-Mc/s Triode Amplifier.—E. M. Ostlund & H. G. Miller.
194. Guiding Principles in Production of Submillimeter Waves.—H. von Foorster & J. S. Schaffner.

621.392 **2123**

**Properties of Some Wide-Band Phase-Splitting Networks.**—F. E. Bond : D. G. C. Luck. (*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 285–287.) Comment on 1614 of 1949 and author's reply.

621.392 : 621.3.016.352 **2124**

**On Stability of Linear Varying-Parameter Systems.**—L. A. Zadeh. (*J. appl. Phys.*, April 1951, Vol. 22, No. 4, pp. 402–405.) A linear varying-parameter system is defined to be stable if and only if every bounded input produces a bounded output. The necessary and sufficient conditions for stability are derived analytically, the result representing a generalization of the frequency-domain criterion commonly used for fixed systems. The theory is applied to investigate the stability of a variable-feedback system.

621.392.4.012 **2125**

**Loci of Complex Impedance and Admittance Functions.**—E. L. Michaels. (*Elect. Engng, N.Y.*, Feb. 1951, Vol. 70, No. 2, p. 127.) Digest of A.I.E.E. 1951 Winter General Meeting paper. Complex impedance diagrams are given for four basic 2-terminal 3-element dissipative networks, and the relations between them are discussed.

621.392.5 : 621.317.755 **2126**

**Experimental Testing of Electrical Networks by means of the Unit Function Response.**—van Slooten. (See 2235.)

621.392.52 **2127**

**Filter Design Simplified: Part 1.**—B. Sheffield. (*Audio Engng*, March 1951, Vol. 35, No. 3, pp. 13–14 . . 36.) Presents a method for calculating the constants for low-pass and high-pass filters which eliminates the need for a large number of formulae. The basis of the method is synthesis from half-sections.

621.392.6 **2128**

**Synthesis of $2n$-Terminal Networks.**—V. Belevitch. (*Wireless Engr*, April 1951, Vol. 28, No. 331, pp. 128–129.) By considering the scattering (or efficiency) matrix used in similar investigations (1321 of 1949 and 305 of February) more general results have been obtained and also a solution of the problem of finding all $2n$-terminal networks equivalent at all frequencies to a given network. The results are briefly described; detailed proof will be given in a forthcoming paper.

621.395.62 : 621.395.667 **2129**

**A Continuously Variable Equalizer.**—W. D. Fling. (*Audio Engng*, March 1951, Vol. 35, No. 3, pp. 16–17 . . 31.) Electrical details of the Fairchild Type-627 nonpassive equalizer which enables adjustment of the frequency characteristic of a reproducer to be made at either the low-frequency or high-frequency end of the audio range, or at both ends simultaneously.

621.396.6 + 621.317.7 + 621.38.001.8 **2130**

**Physical Society's Exhibition 1951.**—Wood. (See 2236.)

621.396.611.1 **2131**

**Pendular and Relaxation Oscillations.**—R. Fortrat. (*J. Phys. Radium*, Jan. 1951, Vol. 12, No. 1, pp. 41–50.) Both electrical and mechanical oscillations are considered. Van der Pol's definition of relaxation oscillations is discussed; it is not applicable to most of the oscillations generally accepted as being of relaxation type, which are distinguished from pendular oscillations by their irreversibility. Relaxation oscillations arise in systems which alternate between two states, passing from one state to the other via a cycle made in a given direction. Though in certain cases the element fixing the limiting states may impose an amplitude limit, this is not a general condition in relaxation oscillations. The coupling of relaxation-oscillation systems to pendular-oscillation systems is discussed briefly.

621.396.611.33 **2132**

**The General Design of Triple- and Quadruple-Tuned Circuits.**—T. C. G. Wagner. (*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 279–285.) Relatively simple formulae are derived for the circuit parameters required for a desired amplitude response in triple-tuned and quadruple-tuned circuits. When using these formulae, an almost arbitrary choice of the $Q$ values of the various circuits is permissible. The formulae give virtually explicit values for the coupling coefficients for a given bandwidth and peak/valley ratio. A condition for the physical realizability of triple-tuned circuits is developed. A convenient procedure for tuning multiple-circuit arrangements and setting the coupling coefficients is outlined.

621.396.615 : 621.384.612.2† **2133**

**Pulser for Cyclotron Oscillator.**—Henry & Keys. (See 2255.)

621.396.645.029.4 **2134**

**A 15-Watt Direct-Coupled Amplifier.**—W. B. Fraser. (*Audio Engng*, April 1951, Vol. 35, No. 4, pp. 15–17, 36.) Description, with detailed circuit diagram, of an amplifier suitable for high-quality reproduction of music. The full output of 15 W is attained with an input voltage of 0·35 V r.m.s. Hum and noise voltages are both low.

621.396.822 **2135**

**Theory of the Shot and Johnson Effects.**—H. Dänzer. (*Ann. Phys., Lpz.*, 10th Nov. 1950, Vol. 8, Nos. 3/4, pp. 176–186.) A unified mathematical treatment of the two effects is developed.

## GENERAL PHYSICS

519.211 **2136**

**Method for the Study of Perturbations of Limited Duration.**—G. Rideau. (*C. R. Acad. Sci., Paris*, 2nd April 1951, Vol. 232, No. 14, pp. 1338–1340.) General formulae are derived for calculating the probabilities of transition of a system acted on, during a finite time, by an external potential.

535.312 **2137**

**Reflection in an Inhomogeneous Medium.** — K. Försterling & H. O. Wüster. (*Ann. Phys., Lpz.*, 10th Nov. 1950, Vol. 8, Nos. 3/4, pp. 129–133.) The reflection coefficients are calculated for the case where the dielectric constant varies as a power of one of the co-ordinates.

535.42 **3821**

**An Asymptotic Treatment of Diffraction Problems: Part 2.**—N. G. van Kampen. (*Physica, 's Grav.*, Dec. 1950, Vol. 16, Nos. 11/12, pp. 817–821.) The theory discussed earlier (3119 of 1949) is simplified by making certain approximations. The method is described and applied in examples.

535.43 **2139**

**On the Scattering of Plane Waves by Soft Obstacles: Part 1 — Spherical Obstacles.**—R. W. Hart & E. W. Montroll. (*J. appl. Phys.*, April 1951, Vol. 22, No. 4, pp. 376–386.) An obstacle is considered 'soft' if it subjects an incident wave to only a small phase shift. An approximate theory is developed for the case where $\lambda_0/\lambda_1 < 1{\cdot}5$, where $\lambda_1$ and $\lambda_0$ are respectively the wavelengths in the obstacle and in the surrounding medium. The approximate results obtained are compared, in the optical case, with results obtained numerically by the Bureau of Standards Computing Laboratory.

537.217 + 538.65 **2140**

**Electric and Magnetic Forces between Sphere and Wire.**—W. R. Smythe. (*J. appl. Phys.*, April 1951, Vol. 22, No. 4, pp. 521–522.) Formulae are derived for the interaction force and scalar potential of a dielectric sphere and a charged wire, and for the interaction force and vector potential of a permeable sphere and a current-carrying cylinder.

537.228.2 **2141**

**Notes on the Theory of Electrostriction in Onsager Liquids.**—H. Falkenhagen & H. Jacob. (*Ann. Phys., Lpz.*, 10th Nov. 1950, Vol. 8, Nos. 3/4, pp. 105–108.) Values of the static electrostriction constant for a number of liquids are calculated from Onsager's theory.

537.311.31 : 537.311.5 **2142**

**The Resistance of a Rectangular Metal Plate with an Internal Electrode.**—S. D. Daymond. (*Quart. J. Mech. appl. Math.*, March 1951, Vol. 4, Part 1, pp. 23–28.) A steady current enters a rectangular metal sheet of uniform thickness and conductivity through a small circular electrode within the plate and flows out through an electrode coinciding with the rectangular boundary. The effective resistance of the plate is considered from the theoretical standpoint, a few representative numerical values being derived.

537.52 : 621.395.623.7 **2143**

**Variations of Discharge Parameters in Preliminary Discharges, and Measurement of Variations.**—W. Fucks. (*Z. Naturf.*, Feb. 1950, Vol. 5a, No. 2, pp. 89–98.) Calculated and observed values are presented for the discharge current, slope and sensitivity in corona and Townsend discharges, for different values of discharge parameters. The relations between the various partial sensitivities, and the behaviour when several parameters are varied simultaneously, are discussed. Applications of the theory in measurement technique are illustrated, including the recording of the vibrations of a loudspeaker diaphragm.

537.523 **2144**

**Positive-Ion Formation in Air prior to High-Frequency Breakdown.**—R. Fatehchand. (*Nature, Lond.*, 7th April 1951, Vol. 167, No. 4249, pp. 566–567.) Results of experiments appear to show that positive ions oscillating in an air gap just prior to breakdown are effective in reducing the h.f. breakdown voltage below the 50-c/s value.

537.523.3 **2145**

**Electrical and Optical Characteristics of D.C. Corona Discharge.**—H. M. Gaunt & J. D. Craggs. (*Nature, Lond.*, 21st April 1951, Vol. 167, No. 4251, pp. 647–648.)

537.525 **2146**

**The Role of the Self Magnetic Field in High Current Gas Discharges.**—P. C. Thonemann & W. T. Cowhig. (*Proc. phys. Soc.*, 1st April 1951, Vol. 64, No. 376B, pp. 345–354.)

537.525 **2147**

**A Study of a High-Current Toroidal Ring Discharge.**—A. A. Ware. (*Philos. Trans. A*, 13th March 1951, Vol. 243, No. 863, pp. 197–220.) The exciting primary is a metal coating on the outside of the torus, the excitation frequency being 150 kc/s. The waveforms of the currents and electric fields and the light from the discharge were studied, the gases used being H and A. Very large currents flow in the gas, with peak values $>10^4$ A; the current is in phase with the electric field. H.f. oscillations of frequency 1–5 Mc/s, thought to be plasma ion oscillations, are observed in the gas.

537.529 : 621.315.611 **2148**

**The Mechanism of Electrical Breakdown in Solid Insulating Materials.**—W. Franz. (*Z. angew. Phys.*, Feb. 1951, Vol. 3, No. 2, pp. 72–80.) A survey paper. The difficulties inherent in breakdown measurements are discussed, and earlier theoretical explanations are reviewed. Experiments made by von Hippel in 1936 proved that the breakdown current in solid insulators is carried by electrons. The mechanism may in some cases be impact ionization, involving increase of breakdown field strength with rise of temperature. An alternative possibility is that free electrons are produced by tunnel effect (internal field emission), a temperature-independent process. At temperatures above room temperature a decrease in dielectric strength with temperature rise is observed for all materials; only tentative qualitative explanations of this phenomenon have so far been advanced.

537.533 : 538.3.029.6 **2149**

**Quantum Effects in the Interaction between Free Electrons and Electromagnetic Fields.**—C. Shulman. (*Phys. Rev.*, 1st April 1951, Vol. 82, No. 1, pp. 116–117.) Description of a method by which the quantum dispersion in the energy exchange between free electrons and an e.m. field has been observed. See also 3196 of 1950 (Ward).

537.562 **2150**

**Dynamics of Plasma: Part 1—Fundamental Equations, Plasma in Crossed Fields.**—A. Schlüter. (*Z. Naturf.*, Feb. 1950, Vol. 5a, No. 2, pp. 72–78.) Equations of motion and diffusion are derived, taking into account friction and electromagnetic interaction. The system is considered for static electric and magnetic fields. It is meaningless to say that conductivity is reduced by a magnetic field, or to refer to a Hall effect in the plasma, since the ponderomotive forces of the current in the magnetic field must be compensated by pressures which in turn affect the current in such a way that its intensity has everywhere exactly that value which it would have in the absence of the magnetic field, with the same pressure. In the case when the magnetic field is due only to the current flowing as a result of a uniform electric field, the plasma contracts to a thread.

537.562 : 538.561 **2151**

**Plasma Oscillations in a Static Magnetic Field.**—E. P. Gross. (*Phys. Rev.*, 15th April 1951, Vol. 82, No. 2, pp. 232–242.) A theory for small-amplitude oscillations of an ionized gas in a static magnetic field is developed, including the effects of temperature motions. Exact expressions are obtained for the distribution function and dispersion relation. The latter shows that gaps in the spectrum exist at frequencies which are approximate multiples of $eH/mc$, the gap widths being temperature-dependent. These gaps may be expected to give rise to selective reflection of incident radiation of appropriate frequency. The results of the exact theory are compared with simplified treatments based on the transport equations, and also with the work of Malmfors (2764 of 1950).

537.562 : 538.566 **2152**

**On Waves in an Ionized Gas.**—E. Åström. (*Ark. Fys.*, 25th Jan. 1951, Vol. 2, Part 5, pp. 443–457.) A theoretical treatment of the interaction between electromagnetic fields and gaseous ions, in which motion of the ions and of neutral molecules is taken into account. For a plasma the dielectric properties are expressed in tensor form. Plane waves are propagated at various angles to the magnetic field, their velocities being related to the direction angle and to the frequency by three-dimensional characteristics, some of which are illustrated. At frequencies well below the ion gyrofrequencies, both 'ordinary' and 'extraordinary' magneto-hydrodynamic waves are propagated. The electric field and displacement, magnetic induction, current density, propagation velocity and energy are evaluated. In general, a transition to longitudinal pressure waves results.

538.21 : 534.111 **2153**

**The Oscillations of Magnetic Suspensions.**—K. Millsaps & J. C. McPherson. (*J. appl. Phys.*, April 1951, Vol. 22, No. 4, pp. 429–432.)

538.221 **2154**

**Collective Electron Ferromagnetism: Rectangular Energy Bands.**—E. P. Wohlfarth. (*Phil. Mag.*, April 1951, Vol. 42, No. 327, pp. 374–390.) Calculations similar to those of Stoner are carried out for an energy band for which the energy density of states is constant.

538.311 **2155**

**The Field Induced by an Oscillating Magnetic Dipole outside a Semi-infinite Conductor.**—A. N. Gordon. (*Quart. J. Mech. appl. Math.*, March 1951, Vol. 4, Part 1, pp. 106–115.) "Formulae are given for the external field produced by an oscillating magnetic dipole located outside a uniform semi-infinite conductor. The normal component of the field induced by a circular alternating current filament at the surface of the conductor is also considered."

538.51 **2156**

**Electromagnetic Induction in a Uniform Semi-infinite Conductor.**—A. N. Gordon. (*Quart. J. Mech. appl. Math.*, March 1951, Vol. 4, Part 1, pp. 116–128.) A systematic treatment of the problem of the induction of currents in a uniform semi-infinite conductor by external magnetic or electric fields is given, attention being drawn to the complementary nature of the magnetic and electric cases. A one-dimensional heat-flow analogue is considered which enables the familiar methods developed in connection with heat conduction to be applied directly to the solution of corresponding problems in e.m. induction.

538.56 + 535.13 **2157**

**Two Theorems concerning the Propagation of Waves in Stratified Media.**—F. Abelès. (*C. R. Acad. Sci., Paris*, 9th April 1951, Vol. 232, No. 15, pp. 1415–1417.) Formulae are proved expressing amplitude and phase relations for wave components transmitted and reflected by a system comprising a transparent stratified medium between two transparent uniform media. It is concluded that measurements made on such a system can provide data permitting determination of the characteristics of the stratified medium if the parameters of the adjacent media are known, but will not enable the parameters (e.g. refractive index) of the two uniform media to be determined.

538.56 **2158**

**1951 I.R.E. National Convention Program.**—(*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 292–315.) Summaries are given of the following papers:

112. Microwave Methods in Gas Analysis.—J. Weber.
136. Propagation of Microwaves between Parallel Conducting Surfaces.—K. S. Kunz.
137. Phase Shift of Microwaves in Passage through Parallel-Plate Arrays.—D. J. Epstein.

538.56 : 535.42 **2159**

**Diffraction Pattern of Microwaves near Rods.**—C. L. Andrews. (*J. appl. Phys.*, April 1951, Vol. 22, No. 4, pp. 465–468.) Rigorous calculations of the field in the neighbourhood of a $\lambda/2$ rod were compared with measured values, for a wavelength of 8 cm. The closeness of agreement found suggests that microwave measurements within a few wavelengths of diffracting objects will afford a useful method of dealing with diffraction problems.

538.566 : 535.421 **2160**

**On the Diffraction of Electromagnetic Waves by Small Circular Disks and Holes.**—C. J. Bouwkamp. (*Philips Res. Rep.*, Dec. 1950, Vol. 5, No. 6, pp. 401–422.) The case is considered of a plane-polarized wave incident normally on a conducting disk. "Integro-differential equations are derived for the currents induced in the disk. These equations are approximately solved on the assumption that the radius of the disk is small compared to the wavelength. Six terms of a power-series solution in the basic variable *ka* are derived, where *k* is the wave number and *a* the radius of the disk. The scattered field on the surface of the disk is calculated, to the same degree of accuracy, and also the field in the wave zone. An expression is obtained for the scattering coefficient of the disk. Finally, Babinet's principle is applied to obtain the corresponding solution for the diffraction of a plane wave by a circular hole in an infinite plane conducting screen."

538.569.4 **2161**

**Microwave Spectroscopy.**—R. Honerjäger. (*Naturwissenschaften*, Jan. 1951, Vol. 38, No. 2, pp. 34–39.) Current methods of investigating molecular spectra, using reflex-klystron generators, waveguides and crystal detectors, are surveyed briefly. Spectra obtained with ammonia and hydrogen are discussed.

538.569.4 **2162**

**Absorption of U.H.F. Radio Waves in some Substituted Benzene Compounds.**—S. N. Sen. (*Indian J. Phys.*, April 1950, Vol. 24, No. 4, pp. 163–170.) Measurements made in the frequency range 250–530 Mc/s and the temperature range 27° to −94°C are reported and discussed. The substances investigated were chlorobenzene, toluene, ethyl benzene and nitrobenzene.

538.632 : 538.221 **2163**

**On the Hall Effect in Ferromagnetics.**—N. Rostoker & E. M. Pugh. (*Phys. Rev.*, 1st April 1951, Vol. 82, No.1, pp. 125–126.) The anomalous behaviour of the Hall constant in the neighbourhood of the Curie point, indicated by experimental data, is eliminated by separation of the extraordinary Hall effect due to intrinsic magnetization from the ordinary Hall effect due to a uniform field. See also 620 of March (Pugh, Rostoker & Schindler).

621.3.011.4 **2164**

**The Capacitance of a Parallel-Plate Condenser with an Anisotropic Dielectric Cylinder in Torsion between its Plates.**—C. Mack. (*Phil Mag.*, April 1951, Vol. 42, No. 327, pp. 428–431.) Summary only. The case in which the cylinder is midway between the plates is considered in detail; an approximate solution is also obtained for the general case.

537/538 **2165**

**Static and Dynamic Electricity.** [Book Review]—W. R. Smythe. Publishers: McGraw-Hill, New York, 2nd edn 1950, 583 pp., $8.50. (*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, p. 321.) "The new edition offers substantial improvements of old material and important additions of new material . . . The presentation is extremely thorough . . . It should appeal to research men and to capable graduate students in mathematics, physics and electrical engineering."

## GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.72 + 523.854] : 621.396.822 **2166**

**Electromagnetic Radiation from Cosmic Protons in the Intense Magnetic Fields of Celestial Bodies.**—B. Kwal. (*J. Phys. Radium*, Jan. 1951, Vol. 12, No. 1, pp. 66–67.) The possibility of interpreting the r.f. radiation from the sun and the galaxy as due to radiation from cosmic protons subjected to intense magnetic fields (1142 of May) is supported by estimates of the frequency and intensity of the radiations based on reasonable assumed values for the energy and concentration of the protons and for the field strength at active areas of the sun's surface.

523.72 : 621.396.822 **2167**

**Motion in the Solar Atmosphere as Deduced from Radio Measurements.**—G. Reber. (*Science*, 23rd March 1951, Vol. 113, No. 2934, pp. 312–314.) R.f. radiations from the sun are assumed to have their origin at different levels of the solar atmosphere, the higher frequencies being associated with the lower levels. Hence motion of material thrown up during a flare may possibly be detected by observing the starting times of the transients, of progressively lower frequencies, produced by its passage through the solar atmosphere. Data from several observatories, obtained on 12th July 1950, are presented. The peak intensity of the disturbance recorded varied from 3 times quiet-sun level at 9·5 kMc/s to 10 000 times quiet-sun level at 51 Mc/s. It is inferred from the observations that material was thrown up to a height corresponding to 35-Mc/s radiation, after which some of it fell back and dispersed. Heights corresponding to the generation of various frequencies are deduced. Speculative values given for the velocity of the material are commensurate with the velocities of particles causing ionospheric and geomagnetic storms.

523.72 : 621.396.822 **2168**

**Radio Observations of Two Large Solar Disturbances.**—W. N. Christiansen, J. V. Hindman, A. G. Little, R. Payne-Scott, D. E. Yabsley & C. W. Allen. (*Aust. J. sci. Res., Ser. A*, March 1951, Vol. 4, No. 1, pp. 51–61.) Two exceptionally large disturbances were observed respectively on 17th and 21st–22nd February 1950, on seven radio receivers working on different frequency bands in the range 62 Mc/s–9·4 kMc/s. The r.f. power flux was recorded continuously at each frequency, the polarization of the radiation was examined at four frequencies, and the apparent position of origin of the radiation was determined at one frequency. The commencement times and the durations of the disturbances at the different frequencies were compared with each other and with corresponding observations of solar flares, radio fade-outs and geomagnetic effects. Similarities and differences between the two disturbances are tabulated.

523.72 : 621.396.822 **2169**

**Observations of the Spectrum of High-Intensity Solar Radiation at Metre Wavelengths: Part 3—Isolated Bursts.**—J. P. Wild. (*Aust. J. sci. Res., Ser. A*, Dec. 1950, Vol. 3, No. 4, pp. 541–557.) "Observations are described of the spectrum of 'isolated bursts' of solar radio-frequency radiation in the frequency range 70–130 Mc/s. These bursts last for a few seconds and have a bandwidth of the order of tens of megacycles per second. Prior observations indicate that they are not circularly polarized. They occur sporadically, often in small groups; many hours sometimes elapse between successive bursts or groups. Although, in general, their spectra show diverse features, some of them (referred to as 'type III' bursts) are of a distinct type characterized by a rapid drift, with time, of the frequency of maximum intensity towards the lower frequencies, at a rate of the order of 20 Mc/s per second. Characteristics of the spectra of type III bursts are described in detail. The results are discussed and hypotheses of origin examined. It is shown in particular that the frequency drift of type III bursts cannot be attributed to the selective group retardation of waves in the solar atmosphere emanating from a fixed source. The frequency drift may, however, be associated with the rapid motion of a source travelling outwards through the solar atmosphere." Part 2: 1630 of July.

523.72 : 621.396.822 **2170**

**Observations of the Spectrum of High-Intensity Solar Radiation at Metre Wavelengths: Part 4—Enhanced**

**Radiation.**—J. P. Wild. (*Aust. J. sci. Res., Ser. A*, March 1951, Vol. 4, No. 1, pp. 36–50.) "Observations are described of the spectrum of 'enhanced radiation' from the Sun (i.e. the radio-frequency radiation which maintains a high but variable level for periods of hours' or days' duration) in the frequency range 70–130 Mc/s. This radiation is known to be received from the direction of sunspots and to show circular polarization. For the purpose of presenting results, two components are recognized, viz. a background continuum which varies gradually with time and frequency, and short-lived, narrow-band bursts ('storm bursts'). The behaviour of the two components, and the relation between them during periods of high level ('noise storms') are described. A detailed analysis is given of the properties of recorded storm bursts. The distribution of recorded bursts with frequency was found to be markedly non-uniform, e.g. a pronounced minimum at 89 Mc/s was present. The possibility that the background continuum is due to the resultant of a large number of bursts is discussed." Part 3: 2169 above.

523.72 : 621.396.822 **2171**

**A Long-Period Change in Radio-Frequency Radiation from the 'Quiet' Sun at Decimetre Wave-Lengths.**—W. N. Christiansen & J. V. Hindman. (*Nature, Lond.*, 21st April 1951, Vol. 167, No. 4251, pp. 635–637.) The effective temperature of the sun at decimetre and centimetre wavelengths is related approximately linearly to the existing sunspot area, and extrapolation to zero sunspot area gives the quiet-sun or base temperature. A marked decrease in this quantity has been observed in the later months of 1950 on wavelengths of 10–50 cm, with the greatest effect (45%) at 25 cm; no change has been found at wavelengths of 3 cm and 150 cm. These results confirm the solar-cycle variations of the base temperature predicted by van de Hulst (*ibid*, 1949, Vol. 163, p. 24) on the basis of an observed decrease in the coronal electron density towards sunspot minimum.

523.852.2 : 621.396.822 **2172**

**Fluctuations in the Intensity of Radio Waves from Galactic Sources.**—C. G. Little & A. Maxwell. (*Phil. Mag.*, March 1951, Vol. 42, No. 326, pp. 267–278.) A description of observations of the two most intense sources, in the constellations of Cygnus and Cassiopeia, taken over a wide range of angles of elevation. At high angles of elevation the radio fluctuations are shown to be correlated with the occurrence of 'spread' ionospheric echoes from the F region. When the sources are low on the northern horizon fluctuations are always observed; these are probably introduced by the passage of radio waves through the continuously disturbed ionospheric regions at high magnetic latitudes. Spaced-receiver observations taken over base lines of 0·1, 4 and 11 km enable the scale of the radio energy diffraction pattern across the ground to be determined. See also 1365 (Smith) and 1366 (Little & Lovell) of June.

538.12 : 523.8 **2173**

**The Origin of the Magnetic Fields of Stars and in Interstellar Space.**—L. Biermann. (*Z. Naturf.*, Feb. 1950, Vol. 5a, No. 2, pp. 65–71.) When stationary, rotational, non-mass-proportional forces act in a plasma, electric currents must flow. Such currents must generate fields of considerable strength in the interior of the stars. These effects are investigated qualitatively for various cases.

550.38 "1950" **2174**

**Indices of Geomagnetic Activity of the Observatories Abinger (*Ab*), Eskdalemuir (*Es*), Lerwick (*Le*) January to December 1950.**—(*J. atmos. terr. Phys.*, 1951, Vol. 1, No. 4, pp. 254–260.) Three-hour *K*-indices are tabulated.

550.385 **2175**

**Geomagnetic "Sudden Commencements" at Lerwick.**—D. H. McIntosh. (*J. atmos. terr. Phys.*, 1951, Vol. 1, No. 4, pp. 223–232.) A study covering a period of about 15 years is reported, movements of the magnetograph trace being classified according to their form and according to the size of the following disturbance. The forms of movements corresponding to 'sudden commencements' vary widely, but are related to the hour of occurrence. No marked relation is found between this systematic variation of form and normal diurnal movements on either geomagnetically quiet or disturbed days. The average effect of all Lerwick sudden commencements is shown to be opposed to the main disturbance field.

551.510.3 : 535.325 **2176**

**Fluctuations in the Refractive Index of the Atmosphere at Microwave Frequencies.**—G. Birnbaum. (*Phys. Rev.*, 1st April 1951, Vol. 82, No. 1, pp. 110–111.) The instantaneous refractive index varies rapidly and irregularly about a mean value. Some indication of the size of the random inhomogeneities is obtained by observing the instantaneous differences in refractive index at varying distances and determining a correlation coefficient. Typical fluctuation records and variation of correlation coefficient with distance are shown.

551.510.535 **2177**

**Determination of Electron Densities in the Ionosphere from Experimental (*h'*, *f*) Curves.**—H. A. Whale. (*J. atmos. terr. Phys.*, 1951, Vol. 1, No. 4, pp. 244–253.) Calculations of electron-density distributions in the ionosphere from observed (*h'*, *f*) curves are facilitated by use of a differential analyser. The simple method, neglecting the earth's magnetic field, leads to inacceptable results; a modified method making an approximate allowance for this field is described, and the results obtained are shown to be feasible.

551.510.535 **2178**

**Fine Structure of the Ionospheric Region E.**—H. A. Whale. (*J. atmos. terr. Phys.*, 1951, Vol. 1, No. 4, pp. 233–243.) Examples are given of complex structure in the normal E layer over South-East England, observed during the period April 1949–March 1950, and the ionization distributions deduced are discussed in terms of simplified models. Both thin and thick 'ledges' are found above and below the level of maximum ionization of the normal E layer, and the complex variations of their height with time are studied.

551.510.535 **2179**

**Winds and Turbulence in the Upper Atmosphere.**—(*Nature, Lond.*, 21st April 1951, Vol. 167, No. 4251, pp. 626–628.) Report of a geophysical discussion held in the rooms of the Royal Astronomical Society on 23rd February 1951. Most of the radio methods of investigation described involved spaced-receiver measurements on waves reflected from or transmitted through the ionosphere; the characteristics examined included amplitude, direction of arrival and equivalent path. The results obtained show that horizontal irregularities of sizes ranging from 200 m to 500 km occur at heights of 90 km or more, with random turbulent speeds of 1–25 m/sec. Drift velocities of 30–50 m/sec in various directions have been noted. Meteorological evidence relating to these data suggests that temperature differences provide the most probable source of energy for the wind-like motions.

551.510.535 **2180**

**A Review of Upper Atmosphere Research from Rockets.**—H. E. Newell, Jr. (*Trans. Amer. geophys. Union*, Feb. 1950, Vol. 31, No. 1, pp. 25–34.) The features of the rocket as a research tool are discussed, and results obtained in various branches of research are presented. Rough measurements of the electron density in the ionosphere indicate values of less than $10^4$ per $cm^3$ below 80 km, rising to $2 \times 10^5$ per $cm^3$ between 100 and 111 km.

551.510.535 : 523.3 : 621.396.11 **2181**

**Moon Echoes and Transmission through the Ionosphere.**—Kerr & Shain. (See 2264.)

551.594.21 **2182**

**The Electrical Processes in the Intervals between the Strokes of a Lightning Discharge.**—D. J. Malan & B. F. J. Schonland. (*Proc. roy. Soc. A*, 10th April 1951, Vol. 206, No. 1085, pp. 145–163.) The fluxmeter described in 2281 of 1950 was used to record the fields of thunderclouds in the intervals between 388 strokes of 105 flashes to ground at various distances. Most of the interstroke interval is occupied by slow field change which is negative for distances <5 km and positive for distances >12 km. The charged regions involved in separate strokes are thought to form a single continuous column extending nearly vertically and sometimes over 6 km in extent. A mechanism is proposed to account for the intermittent discharge of this column, and evidence from field-change records is adduced in support of the theory.

551.594.22 **2183**

**Lightning Discharges upwards from Thunderclouds.**—R. Mühleisen. (*Naturwissenschaften*, March 1951, Vol. 38, No. 6, p. 140.) Discharges observed on 1st July 1950, at Rüdern über Esslingen a.N., are briefly described.

551.594.6 **2184**

**On the Reflection of Atmospherics from the Ionosphere at Night: Part 1.**—M. W. Chiplonkar & M. S. Hattiangadi. (*Proc. Indian Acad. Sci. A*, June 1945, Vol. 21, No. 6, pp. 265–271.) A brief description of apparatus for recording the waveforms of atmospherics. The main features are an amplifier with uniform gain from 50 c/s to 300 kc/s, a c.r.o. display and a drum camera. Results quoted were derived from echo-type waveforms recorded at night, the storms being mainly at distances between 200 and 800 km. Values derived for the height of reflection were nearly all between 80 and 100 km.

551.594.6 **2185**

**On the Reflection of Atmospherics from the Ionosphere at Night: Part 2.**—M. W. Chiplonkar & M. S. Hattiangadi. (*Proc. Indian Acad. Sci. A*, Nov. 1949, Vol. 30, No. 5, pp. 223–236.) Waveforms of atmospherics, recorded by a previously reported method (2184 above) are analysed statistically. Histograms of the following quantities are plotted: height of reflection, distance of origin, reflection coefficient of the ionosphere, duration of main pulse, field strength. The number and nature of the ionospheric echoes, the peak power of the atmospherics and the occurrence of precursors are also discussed.

## LOCATION AND AIDS TO NAVIGATION

621.396.9 **2186**

**1951 I.R.E. National Convention Program.**—(*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 292–315.) Summaries are given of the following papers:

13. Stagger-Tuned Loop Antennas for Wide-Band Low-Frequency [loran] Reception.—D. K. Cheng & R. A. Galbraith.
108. Aircraft and Airport Characteristics.—L. P. Tabor.
109. Economic Demand.—F. B. Lee.
110. Human Engineering.—P. M. Fitts.
111. Traffic Control Theory.—D. H. Ewing.
138. On the Measurement of the Radar Echoing Areas of Conducting Bodies.—J. R. Mentzer.
139. Polarization Properties of Target Reflections.—E. M. Kennaugh.
140. The Use of Circular Polarization as a Means of Reducing Radar Precipitation Return.—W. D. White.
141. An I.C.W. System for Distance Measurement.—J. Lyman, G. B. Litchford & C. Grunsky.
142. Effects of Vertical Radiation Pattern on Omnirange-Beacon Characteristics.—S. Pickles.

621.396.9 **2187**

**Development of Radar in the** [French] **Navy.**—E. Giboin. (*Onde élect.*, Feb. 1951, Vol. 31, No. 287, pp. 53–64.) Illustrated review discussing particularly wartime experiments and equipping of warships, the requirements for centralized control, and the suitability of different wavelengths for air surveillance, surface radar, etc.

621.396.932 **2188**

**Marine Radio Position Fixing Systems.**—(*J. Inst. Nav.*, Oct. 1950, Vol. 3, No. 4, pp. 317–356.) A symposium of four papers read at a meeting of the Royal Geographical Society in May 1950, giving an account of the four most widely used systems. The titles are:

Marine Position Fixing Systems in Use To-day.—H. E. Hogben.
Use of Direction Finding at Sea.—F. P. Best.
The Adoption of Decca as an Aid to Navigation at Sea.—E. Fennessy.
The Use of Consol in the Fishing Fleet.—D. H. Harper.

The discussion is included.

621.396.933 **2189**

**Microwave Direction Finding for Aircraft Navigation.**—V. D. Burgmann & K. V. Sheridan. (*J. Inst. Nav.*, July 1950, Vol. 3, No. 3, pp. 251–269.) An aircraft direction finder operating in the 3-cm wavelength band is used to observe the bearings of fixed beacons on different spot frequencies. Frequency sweep on the receiver enables the frequency (for identification) and bearing to be displayed in rectangular coordinates on a c.r. tube. Tests to determine the value of the system for homing, for maintaining a track and for various other purposes are described.

621.396.933 **2190**

**The Development of the Aircraft Automatic Radio Compass.**—J. H. Moon. (*J. Inst. Nav.*, Oct. 1950, Vol. 3, No. 4, pp. 393–403.) Major problems encountered in the development of airborne d.f. equipment are reviewed, and a description is given of the latest electrical and mechanical improvements evolved to provide fast-moving aircraft with instantaneous position indication. Various ways of using the information provided by the direction finder are discussed, and questions of calibration and ultimate accuracy are considered.

621.396.933 : 621.396.61 **2191**

**Design of a Loran Transmitter.**—Myers. (See 2300.)

621.396.933 : 629.13.053 **2192**

**Automatic Course Plotting.**—(*Wireless World*, April 1951, Vol. 57, No. 4, pp. 143–144.) Describes a device for connection to a normal Decca receiver to give a continuous map display of position. A chart is moved automatically in one direction while a cursor carrying a stylus is moved over it at right angles to this direction. The coordinates of each of the fifteen charts in the instrument are derived indirectly from the hyperbolic lattice in one of nine ways so as to give minimum distortion of the mapped area.

621.396.933.4 : 621.39.001.11 **2193**

**Application of the Information Theory to System Design.**—Tuller. (See 2274.)

## MATERIALS AND SUBSIDIARY TECHNIQUES

53 + 621.3 **2194**

**1951 I.R.E. National Convention Program.**—(*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 292–315.) Summaries are given of the following papers:

100. New Vacuum-Tube Materials.—E. B. Fehr & A. P. Haase.
101. Properties of Interfaces in Metal to Ceramic Seals.—W. A. Christoffers & R. P. Wellinger.
113. Spark-Over of Air at Radio Frequencies.—W. Caywood, Jr.

537.226.1 **2195**

**On the Static Dielectric Constant of Dipolar Solids.**—J. H. Simpson. (*Canad. J. Phys.*, March 1951, Vol. 29, No. 2, pp. 163–173.) Fröhlich's general formula for the static dielectric constant is applied to a material having a cubic arrangement of dipolar molecules, each of which has two equilibrium positions 180° apart and short-range ordering forces tending to make nearest neighbours antiparallel. Values yielded by the theory are compared with experimental results.

537.311.3 : 537.226 : 539.23 **2196**

**Electron-Bombardment Conductivity of Dielectric Films.**—F. Ansbacher & W. Ehrenberg. (*Proc. phys. Soc.*, 1st April 1951, Vol. 64, No. 376A, pp. 362–379.) An experimental investigation is reported. The ratio of current through the film to bombarding current increases strongly with temperature; the value of this ratio may reach 40 000 for $As_2S_3$ films. The theory of the effect is discussed.

537.311.33 **2197**

**Lattice-Imperfection Phenomena and Substitution Processes in Electron-Conducting Mixed Phases.**—K. Hauffe. (*Ann. Phys., Lpz.*, 10th Nov. 1950, Vol. 8, Nos. 3/4, pp. 201–210.) The Wagner-Schottky lattice-imperfection theory is extended to heterotype mixed phases in which conduction is electronic. It is established by means of models and experiments that conductivity variations consequent upon addition of high-valency or low-valency oxides to a first oxide are in conformity with semiconductor theory, the following laws being found: (*a*) the conductivity of hole conductors is increased by addition of low-valency cations and decreased by addition of high-valency cations; (*b*) the variations are reversed for excess-electron conductors; (*c*) the conductivity of intrinsic semiconductors increases with addition of either high- or low-valency cations. The laws found enable predictions to be made about the effect of addition of foreign metals on the rate of scale formation in metal alloys.

537.311.33 **2198**

**A Note on the Dielectric Dispersion in Polycrystalline Materials.**—E. Billig & K. W. Plessner. (*Proc. phys. Soc.*, 1st April 1951, Vol. 64, No. 376B, pp. 361–363.) An equivalent circuit is postulated, consisting of two parallel-RC circuits in series, to represent the lumped grain and boundary impedances respectively. Using parameters typical of the selenium in standard rectifiers, the variation of apparent resistivity, permittivity and power factor with frequency are calculated.

537.311.33 **2199**

**Electrical Properties of Grey Tin.**—A. I. Blum & N. A. Goryunova. (*C. R. Acad. Sci. U.R.S.S.*, 21st Nov. 1950, Vol. 75, No. 3, pp. 367–370. In Russian.) Measurements of conductivity and Hall effect for grey tin and white tin are compared. Whereas white tin is a metal, grey tin is a semiconductor of the same group as Si and Ge, with a charge-carrier concentration of $10^{19}/\text{cm}^3$ at 20°C.

537.311.33 : 537.312.6 : 546.48-31 **2200**

**The Variation with Temperature of the Electrical Properties of a Degenerate Electronic Semiconductor as exemplified by Cadmium Oxide.**—R. W. Wright. (*Proc. phys. Soc.*, 1st April 1951, Vol. 64, No. 376A, pp. 350–362.) Measurements of conductivity, Hall constant and thermoelectric power of CdO over the range 0–500°C indicate metallic properties, i.e. constant concentration of free electrons ($\sim 1{\cdot}7 \times 10^{19}/\text{cm}^3$). The theory of electronic conduction in an ionic lattice is discussed and related to the experimental data.

537.311.33 : 546.289 : 669-15 **2201**

**Effect of Heat Treatment on the Electrical Properties of Germanium.**—H. C. Theuerer & J. H. Scaff. (*J. Metals*, Jan. 1951, Vol. 191, No. 1, pp. 59–63.) Germanium may be reversibly converted from $n$ to $p$ type by heat treatment. Data for the conversion and the associated changes in resistivity are given and the results are interpreted in terms of changes in the donor-acceptor balance.

538.221 **2202**

**On the Conditions of the Occurrence of Ferromagnetism in Metal Compounds and in Solutions.**—P. F. Váradi. (*Physica, 's Grav.*, Dec. 1950, Vol. 16, Nos. 11/12, p. 920.) Statement of conditions based on Gisolf's theory (2237 of 1950) and earlier data.

538.221 **2203**

**Ferromagnetism of the Alloy $FeBe_2$.**—A. J. P. Meyer & P. Taglang. (*C. R. Acad. Sci., Paris*, 23rd April 1951, Vol. 232, No. 17, pp. 1545–1546.)

538.221 **2204**

**Introduction to the Application of 'Ferroxcube'.**—H. van Suchtelen. (*Philips tech. Commun., Aust.*, 1951, No. 1, pp. 14–24.) A general account of the essential properties required in magnetic materials for cores and of the terminology used in discussing them.

538.221 : 538.24 **2205**

**The Magnetization Process in Ferrites.**—J. J. Went & H. P. J. Wijn. (*Phys. Rev.*, 15th April 1951, Vol. 82, No. 2, pp. 269–270.)

538.632 : 621.315.592† **2206**

**Resistivity and Hall Constant of Semiconductors.**—C. N. Klahr. (*Phys. Rev.*, 1st April 1951, Vol. 82, No. 1, pp. 109–110.) Comment on 1357 of June (Jones).

546.431.82 **2207**

**Temporary Enhancement of Hysteresis in Barium Titanate Samples.**—D. R. Young. (*J. appl. Phys.*, April 1951, Vol. 22, No. 4, pp. 523–524.) Comment on work reported by Rzhanov in *Zh. eksp. teor. Fiz.*, 1949, Vol. 19, pp. 335–345.

548.0 : 537.228.1 **2208**

**Contour Modes of Square Plates excited Piezoelectrically and Determination of Elastic and Piezoelectric Coefficients.**—R. Bechmann. (*Proc. phys. Soc.*, 1st April 1951, Vol. 64, No. 376B, pp. 323–337.) Piezoelectric measurements on square plates provide checks for the theoretical solution of the various modes, and in particular for the distribution of displacement. The reliability of recently published solutions for square plates is discussed. The materials used were $NaClO_3$, $NaBrO_3$, quartz, ADP and EDT. New determinations were made of the elastic and piezoelectric coefficients of these materials, with the exception of EDT, for which results have already been published (see 128 of January).

548.0 : 547.476.3 : 537.228.1 **2209**

**New Ferroelectric Tartrates.**—B. T. Matthias & J. K. Hulm. (*Phys. Rev.*, 1st April 1951, Vol. 82, No. 1, pp. 108–109.)

549.211 : 621.3.011.5 **2210**

**Determination of the Dielectric Constant and Loss Angle of Diamond.**—F. P. Pietermaat & A. de Keuster. (*HF, Brussels,* 1950, No. 8, pp. 215–223.) A method is described using test specimens made from mixtures of diamond dust with glass or paraffin wax, and results are given for a frequency range of 1–40 Mc/s.

621.3.011.5 : 553.623 **2211**

**Electrical Constants of Sand at Ultra High Frequencies.**—S. K. Chatterjee. (*Indian J. Phys.*, April 1950, Vol. 24, No. 4, pp. 143–150.) Measurements were made on dry and moist sand (moisture content up to 5%) over the frequency range 300–500 Mc/s, using a Lecher-wire method. For dry sand, dielectric constant varies from 2·6 to 2·7, conductivity varies from $0{\cdot}26 \times 10^8$ to $1{\cdot}04 \times 10^8$ e.s.u. and loss tangent varies from $64 \times 10^{-3}$ to $153 \times 10^{-3}$ over the frequency range, while the reflection coefficient remains practically unchanged at 0·24, though the phase change on reflection varies with frequency. All the constants increase with increasing moisture content.

621.314.6 : 621.315.59 **2212**

**Thermal Instability of Contact Rectifiers: The Effect of the Constituent Materials on the Efficiency of a Rectifying Junction.**—E. Billig. (*Proc. phys. Soc.*, 1st April 1951, Vol. 64, No. 376B, pp. 342–345.) An expression is given for the power developed, per unit area of the contact, by the leakage current which flows when a voltage is applied in the blocking direction. Thermal instability results when the heat corresponding to this power cannot be dissipated by cooling. The highest inverse voltage that can be sustained indefinitely is governed by the thermal stability, the criterion for which is assumed generally applicable to all rectifiers. The maximum blocking voltage is calculated for the independent variation of semiconductor conductivity and potential-barrier height.

621.318.22 **2213**

**The Performance and Stability of Permanent Magnets.**—A. J. Tyrrell. (*Proc. Instn Radio Engrs, Aust.*, March 1951, Vol. 12, No. 3, pp. 77–84.) Reprint. See 2251 of 1950.

666.2 : 681.3 **2214**

**Glass Selection and Production Techniques for X-Ray and Other Tubes.**—M. J. Zunick & J. B. Gosling. (*Glass Ind.*, March 1951, Vol. 32, No. 3, pp. 117–120, 144.) Discussion of (*a*) changes in techniques necessitated by the transition from soft glasses to the hard borosilicate glasses, and (*b*) the parallel development of suitable sealing metals. Special glass-working lathes are illustrated and processes for the production of heavy glass bulbs are briefly described.

## MATHEMATICS

517.512.2 **2215**

**The Method of Discontinuities in Fourier Analysis.**—J. M. L. Janssen. (*Philips Res. Rep.*, Dec. 1950, Vol. 5, No. 6, pp. 435–460.) Results previously obtained by this method are discussed; a more general conception is practicable starting from the Fourier integrals rather than Fourier series, and the method can then also be used for investigating the frequency spectrum of continuous functions. The border-line between rapid changes and discontinuities is examined; correction factors are derived which take into account the form of the rapid changes. Examples of application of the method are given.

517.9 **2216**

**The Factorization Method.**—L. Infeld & T. E. Hull. (*Rev. mod. Phys.*, Jan. 1951, Vol. 23, No. 1, pp. 21–68.) An operational procedure is described for solving eigenvalue problems. The basic idea is to consider a pair of first-order differential-difference equations which are equivalent to a given second-order differential equation with boundary conditions.

517.93 **2217**

**A Generalization of Reversion Formulae with their Application to Nonlinear Differential Equations.**—A.C. Sim. (*Phil. Mag.*, March 1951, Vol. 42, No. 326, pp. 228–238.) The formulae for algebraic reversion are extended to revert a class of nonintegral power series, and are also generalized to revert series whose coefficients contain operators. These formulae are particularly applicable to the nonlinear differential equations met with in various problems of physics and engineering, which they expand into an infinite sequence of linear equations.

517.93 **2218**

**Finite Representation of Impulse Functions.**—J. J. Smith & P. L. Alger. (*Elect. Engng, N.Y.*, Feb. 1951, Vol. 70, No. 2, p. 143.) Digest of A.I.E.E. 1951 Winter General Meeting paper. The use of differentials ($d^nH$) instead of differential coefficients ($d^nH/dx^n$) leads to equations in finite functions, which can be solved by conventional methods.

517.941.4 : 517.522.5 **2219**

**The Remainder Theorem and its Application to Operational-Calculus Techniques.**—A. S. Richardson, Jr. (*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, p. 287.) Corrections to paper abstracted in 677 of March.

681.142 **2220**

**1951 I.R.E. National Convention Program.**—(*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 292–315.) Summaries are given of the following papers:

37. Drift Compensation in D.C. Amplifiers for Analogue Computers.—W. E. Ingerson.
86. The Raytheon Selection Matrix for Computer and Switching Applications.—K. M. Rehler.
87. Saturable Reactors as Substitutes for Electron Tubes in High-Speed Digital Computers.—J. G. Miles.
88. Ferromagnetic Cores for Three-Dimensional Digital Storage Arrays.—W. N. Papian.
89. Dependable Small-Scale Digital Computer.—J. J. Connolly.
90. An Asynchronous Control for a Digital Computer.—D. H. Gridley.
117. A Sampling Analogue Computer.—J. Broomall & L. Riebman.
118. A Time Division Multiplier for a General Purpose Electronic Differential Analyzer.—R. V. Baum & C. D. Morrill.
119. A High-Speed Product Integrator.—A. B. Macnee.
120. Plug-In Units for Digital Computation.—G. Glinski & S. Lazecki.
121. A Five-Digit Parallel Coder Tube.—J. V. Harrington, K. N. Wulfsberg & G. R. Spencer.

681.142 **2221**

**Programme-Controlled Digital Computers (Electronic Computing Machines).**—H. Rutishauser, A. Speiser & E. Stiefel. (*Z. angew. Math. Phys.*, 15th Sept. & 15th Nov. 1950, Vol. 1, Nos. 5 & 6, pp. 277–297 & 339–362, 15th Jan. & 15th March 1951, Vol. 2, Nos. 1 & 2, pp. 1–25 & 63–92.) A comprehensive review of information at present available on the subject, including fundamental principles, general organization and methods of operation, arithmetical principles, programme arrangements, physical principles and equipment. Automatic computers completed or under construction in various countries up to the end of 1949 are listed, with their principal features, and 67 references are given.

681.142(083.71) **2222**

**Standards on Electronic Computers: Definitions of Terms, 1950.**—(*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 271–277.) Copies of this Standard, 50 IRE 8.S1, may be obtained while available from the I.R.E. at $0.75 per copy.

## MEASUREMENTS AND TEST GEAR

529.7 **2223**

**The Determination of Time and Frequency.**—H. M. Smith. (*Proc. Instn elect. Engrs*, Part II, April 1951, Vol. 98, No. 62, pp. 143–153. Discussion, pp. 164–172.) Where frequency is measured to an accuracy within one part in $10^8$, possible small variations in the unit of time must be considered. The principles involved in the determination of time—an astronomical process—are reviewed. Instruments used or to be used for this purpose at Greenwich are mentioned. Clocks and other equipment are described, together with the methods currently used in the operation of the time service. The standard of accuracy attained is discussed; agreement between Greenwich and the U.S. Naval Observatory is normally within one part in $10^8$ in respect of frequency. In practice two time systems are now employed: Greenwich Mean Time, based directly on the astronomical observations and applicable to surveying and astronavigation, and a more uniform time system which is not yet precisely defined, suitable for accurate work in frequency measurement and in related scientific investigations.

621.3.018.4(083.74) **2224**

**Frequency Standardization.**—L. Essen. (*Proc. Instn elect. Engrs*, Part II, April 1951, Vol. 98, No. 62, pp. 154–164. Discussion, pp. 164–172.) The development and performance of quartz oscillators as frequency standards and timekeepers is reviewed. Some of the causes of frequency drift of these standards are discussed, and suggestions are made for improvement in this respect. An outline is given of methods for measuring frequencies up to 50 kMc/s in terms of quartz standards, also of the frequency control of oscillators by high-*Q* cavity resonators, with application to the atomic clock based on the ammonia absorption line at 23·870 kMc/s.

621.3.018.41(083.74) : 621.317.361 **2225**

**Measuring Time and Frequency in Hawaii.**—V. E. Heaton. (*Tele-Tech*, March 1951, Vol. 10, No. 3, pp. 36–38 . . 91.) Description of routine methods of comparison of WWV and WWVH frequencies.

621.317 **2226**

**1951 I.R.E. National Convention Program.**—(*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 292–315.) Summaries are given of the following papers:

1. A Storage Tube as an Amplitude Distribution Analyzer.—R. E. Nienburg & T. F. Rogers.
23. Precision Frequency Generators using Single-Sideband Suppressed-Carrier Modulators.—H. R. Holloway & H. C. Harris.
25. Wide-Range Direct-Reading Precision Frequency Meter and Signal Source.—B. Parzen.
27. Frequency Stabilization System for Measurement of Microwave Refraction of Gases.—W. F. Gabriel.
33. The Servomodulator: a Low-Level D.C. Instrument.—G. M. Attura.
53. Electronic Instrumentation in A.M., F.M., and TV Broadcasting through Use of the Cathode-Ray Oscillograph.—P. S. Christaldi.
72. Beam Analyzer.—L. R. Bloom, D. F. Holshouser, H. S. Wu & W. W. Cannon.
76. Radial Probe Measurements of Mode Conversion in Large Round Waveguide with $TE_{01}$ Mode Excitation.—M. Aronoff.
81. Four-Gun Oscilloscope.—M. A. Ziniuk.
85. New Techniques in Impulse Testing.—W. G. Fockler.
115. Noise Figure Standards.—M. Solow, I. W. Hammer & P. H. Haas.
116. New Limits for Low-Level R.F. Energy Measurements.—W. K. Volkers.
146. Precise Measurement and Regulation of Magnetic Fields with Radio-Frequency Techniques using Nuclear Resonance.—H. A. Thomas.
147. A High-Precision Magnetic-Field Measuring Instrument.—R. W. Kane, E. C. Levinthal & E. H. Rodgers.
151. A Sweep Frequency Method for Measuring the Transmission-Amplitude Characteristic of a Television Transmitter.—J. Ruston.

621.317(083.74) **2227**

**Standards for Electrical Measurement.**—F. B. Silsbee. (*Elect. Engng, N.Y.*, March 1951, Vol. 70, No. 3, pp. 202–206.) Paper presented at the 1951 A.I.E.E. Winter General Meeting, New York, giving an account of some of the methods in use at the National Bureau of Standards for accurate electrical measurements. A block diagram illustrates the various steps in referring such measurements to the fundamental standards of length, mass and time.

621.317.31 **2228**

**Logarithmic Amplification of Weak Currents using Diodes.**—M. Brière, A. Rogozinski & J. Weill. (*J. Phys. Radium*, Feb. 1951, Vol. 12, No. 2, pp. 144–146.) The logarithmic relation which exists between diode current and anode voltage for negative values of the latter, and which has been used as a basis of measurements, is investigated at very low values. An experimental circuit is described using an under-run multigrid electrometer valve connected as a diode and fed from a source such as an ionization chamber or photocell. The logarithmic portion of the I/V curve may have a current range of $1 : 10^5$, its lower limit depending on the valve used and being as low as $10^{-14}$ A in some cases. Applications to various measurements are indicated.

621.317.331 **2229**

**Measurement of Very High Resistances at High Alternating Voltages.**—H. Petersen. (*Elektrotech. Z.*, 1st Nov. 1950, Vol. 71, No. 21, pp. 577–580.) A development of the Schering loss-measurement bridge in which the parallel combination of C and R in the fourth arm is replaced by a potential divider comprising a very high capacitance in series with a variable resistance. This makes it possible to deal with very high resistances having very low parallel capacitances. The very high capacitance is obtained from a network of three capacitances. The variable resistance is used for phase balancing. Accuracy to within 1% was easily obtained with resistances of 10 000 MΩ at 50 kV.

621.317.335.3† **2230**

**The Use of Special Waveforms in the Study of Linear Dielectric Phenomena.**—E. Laverick. (*J. Brit. Instn Radio Engrs*, March 1951, Vol. 11, No. 3, pp. 81–92.) A survey of the experimental techniques for investigating dielectric phenomena and of the theories suggested in explanation of these phenomena. Most techniques involve the use of sinusoidal signals, but the use of pulsed signals has some advantages. When pulsed signals are used in bridge measurements, with c.r. tube display, differences between the properties of a capacitor including some dielectric and those of networks intended to simulate such a capacitor may be easily distinguished.

621.317.336 : 621.315.212 **2231**

**Pulse Testing of Coaxial Cables.**—A. W. Lebert. (*Bell Lab. Rec.*, April 1951, Vol. 29, No. 4, pp. 153–157.) A brief description is given of equipment used to locate impedance variations in coaxial cables during production. The types of echo received from different types of irregularity are described.

621.317.353 **2232**

**Harmonic Distortion in Iron-Core Transformers.**—T. Williams & R. H. Eastop. (*Audio Engng*, April 1951, Vol. 35, No. 4, pp. 18–20, 33.) Discussion of a simple and inexpensive bridge suitable for routine checks of total distortion. Errors of the method and means of extending it to permit measurement of other important performance parameters are indicated.

621.317.41 **2233**

**Instrument for Production Testing of the Permeability of Magnetic Circuits.**—M. Andrieux & M. Fraize. (*Onde élect.*, Feb. 1951, Vol. 31, No. 287, pp. 65–69.) The principle of the method is the measurement of the no-load secondary voltage of a transformer with constant-current primary feed. The transformer is clamped over the specimen by a simple lever movement. Field strength is adjustable between 2 and 100 millioersted.

621.317.755 : 534.321.7.08 **2234**

**Precise Calibration of Tuning Forks.**—C. C. J. Addink. (*Philips tech. Rev.*, Feb. 1951, Vol. 12, No. 8, pp. 228–232.) The adoption of the new international standard of concert pitch based on $A_3 = 440$ c/s emphasizes the importance of accurate tuning standards. A c.r.o. method is described in which the frequency of the fork is matched with that of an RC oscillator connected to a synchronous clock.

621.317.755 : 621.392.5 **2235**

**Experimental Testing of Electrical Networks by Means of the Unit Function Response.**—J. van Slooten. (*Philips tech. Rev.*, Feb. 1951, Vol. 12, No. 8, pp. 233–239.) Pulses of d.c. are applied to the impedance or network under test by means of a multivibrator which also supplies the timebase voltage for oscilloscopic observation of the response. Several examples (e.g. damped oscillatory circuit, band-pass filter) are discussed particularly. The method is useful where speed is more important than high accuracy.

621.396.6 + 621.317.7 + 621.38.001.8 **2236**

**Physical Society's Exhibition 1951.**—A. B. Wood. (*Nature, Lond.*, 5th May 1951, Vol. 167, No. 4253, pp. 701–704.) A brief survey of the apparatus on show at this exhibition, held from 6th to 11th April. For other accounts see *Wireless Engr*, May 1951, Vol. 28, No. 332, pp. 156–161; *Wireless World*, May 1951, Vol. 57, No. 5, pp. 189–192; *Engineer, Lond.*, 6th–20th April 1951, Vol. 191, Nos. 4967–4969, pp. 442–445, 473–475 & 505–506; *Engineering, Lond.*, 6th–20th April 1951, Vol. 171, Nos. 4445–4447, pp. 409–411, 425–426 & 457–459.

621.396.615.029.426/.51 **2237**

**A Precision Decade Oscillator for 20 c/s to 200 kc/s.**—C. M. Edwards. (*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 277–278.) Circuit details of a RC-coupled test oscillator with frequency accuracy to within 0·1% from 100 c/s to 100 kc/s and to within 0·5% outside this range. Three ranges are provided by capacitance changes by factors of 10, decade arrangements of resistors giving 100-c/s and 10-c/s steps respectively, with a linear potentiometer for continuous variations from 0 to 10 c/s. On the highest range 100 kc/s is added to 100 times the combined dial readings. Good tracking over the wide frequency range is effected by the use of trimmers and a wide-band amplifier.

621.317 **2238**

**Die Messung von elektrischen Schwingungen aller Art nach Frequenz und Amplitude (The Measurement of Electrical Oscillations of All Frequencies and Amplitudes).** [Book Review]—H. Laporte. Publishers: Verlag Wilhelm Knapp, Halle/Sa., 1949, 111 pp., DM 4.20. (*Optik*, Jan./Feb. 1951, Vol. 8, Nos. 1/2, p. 80.) This is the first volume in a series of 'Handbooks of Practical Physics for Scientists and Engineers' and is particularly valuable for demonstrating the evolution of the methods of measurement from ordinary current and voltage measurements at low frequencies to power or energy measurements at centimetre wavelengths and to the counting of quanta for X rays.

621.317.31/.32 **2239**

**Die Messung von elektrischen Spannungen und Strömen aller Art vom Gleichstrom bis zur Hochfrequenz (The Measurement of Electrical Voltages and Currents from Direct Current up to High Frequency).** [Book Review]—H. Laporte. Publishers: Verlag Wilhelm Knapp, Halle/Sa., 1950, 149 pp., DM 5.20. (*Optik*, Jan./Feb. 1951, Vol. 8, Nos. 1/2, p. 80.) Volume 2 of the series 'Handbooks of Practical Physics', mainly for the beginner. Both well-known and less usual methods of measurement are discussed; theory is kept to the minimum, while many numerical data are included. One chapter deals with auxiliary apparatus such as potentiometers and scale-reading magnifiers.

## OTHER APPLICATIONS OF RADIO AND ELECTRONICS

537.226.1 : 541.124 **2240**

**A Dielectric-Constant Method of following the Non-stationary State in Polymerization: Part 1—The Theory of the Method.**—C. M. Burrell, T. G. Majury & H. W. Melville. (*Proc. roy. Soc. A*, 22nd Feb. 1951, Vol. 205, No. 1082, pp. 309–322.) A very sensitive means has been developed for recording small amounts of chemical change occurring in short periods, using the change of dielectric constant accompanying reaction to vary the capacitance of an element in a bridge incorporating a signal generator of special design. Operation is at 40–60 Mc/s.

621-526 **2241**

**Transducers — Sensing Elements for Servos.**—Stovall. (See 2285.)

621.316.7.076.7 **2242**

**On the Regulation of Industrial Processes.**—H. J. Roosdorp. (*Philips tech. Rev.*, Feb. 1951, Vol. 12, No. 8, pp. 221–227.) A general introductory discussion on the automatic control of closed circuits. The advantages of working from an electrical analogue are indicated.

621.317.083.4 : 551.508.11 **2243**

**A New Code Transmitting Radiosonde.**—H. D. Brailsford. (*J. Met.*, Oct. 1949, Vol. 6, No. 5, pp. 360–

362.) The system uses a special disk on which Morse letters are recorded, so that the position of a pickup on the disk is known from the letters transmitted. Three pickups are provided, with angular separations of about 90°, the pickup arms being controlled respectively by an aneroid pressure cell, a bimetal temperature element and a hair hygrometer. The Morse letters are confined to a sector of about 85° on the record, so that the transmitted signal consists of three code groups followed by a pause. Design problems are discussed.

621.365.54† **2244**

**Induction Heating of a Hollow Metal Sphere.**—A. Colombani. (*J. Phys. Radium,* Jan. 1951, Vol. 12, No. 1, pp. 26–30.) Formulae are derived giving the energy absorption as a function of thickness for a thin spherical metal shell in an alternating field; a maximum is exhibited for a particular value of the thickness. The calculation is made without using spherical functions, by introducing the concept of magnetic potentials.

621.38.001.8 **2245**

**1951 I.R.E. National Convention Program.**—(*Proc. Inst. Radio Engrs,* March 1951, Vol. 39, No. 3, pp. 292–315.) Summaries are given of the following papers:

39. Some Biological Applications of Random Nets. —A. Rapoport.
69. The Rotating Beam Method for Investigating Electron Lenses.—D. E. George, R. G. E. Hutter & M. Cooperstein.
82. Automotive Electronic Test Equipment.—R. J. L. Butterer & T. S. Bolton.
83. The Vibrotron — a New Transducer.—J. Ohman & P. M. Erlandson.
84. Electronic Relays in Automatic Process Control Systems.—R. W. Greenwood.
114. X-Ray Liquid Level Gage.—J. E. Jacobs & R. F. Wilson.
144. Timing Unit and Pulse Deflector Generator for 145-Inch Synchro-Cyclotron.—E. M. Williams, C. H. Grace & L. W. Johnson.
145. Design and Construction of a Billion-Volt Linear Electron Accelerator.—M. Chodorow, E. L. Ginzton, J. Jasberg, R. Kyhl, R. Neal & P. Pearson.
157. Telemetry and the Guided-Missile Program.—C. H. Hoeppner.
158. F.M./F.M. Telemetry.—M. V. Kiebert, Jr.
159. Techniques and Applications of F.M./F.M. Telemetry.—W. J. Mayo-Wells.
160. The Case for P.W.M./F.M. Telemetry.—J. R. Kauke.
161. P.T.M. Telemetry.—A. H. Nelson.
185. Simulation — its Place in System Design.—H. H. Goode.
186. Detailed Simulation of a Three-Axis Guided Missile System (Typhoon).—A. W. Vance.
187. The Application of the Simulator to the Design of Automatic Control Systems.—L. Botwin.
188. Real Time Simulation of Feedback Control Systems.—A. C. Hall.
189. Digital Computers in Simulated Control Systems. —J. W. Forrester.

621.38.001.8 **2246**

**An Electronic Instrument for the Measurement of the Damping Capacity of Materials.**—A. D. N. Smith. (*J. sci. Instrum.,* April 1951, Vol. 28, No. 4, pp. 106–108.) The instrument is designed for investigating the internal friction of materials vibrating at frequencies from about 50 c/s to 10 kc/s. The vibrations are detected by means of a pickup, and the time for the vibration amplitude to decay freely to half its initial value is measured by means of a circuit which transmits two pulses to a standard electronic timing instrument.

621.38.001.8 : 373.62 : 656.7.07 **2247**

**Electronic Flight Simulator.**—(*Wireless World,* April 1951, Vol. 57, No. 4, pp. 130–131.) The equipment described is a model of the nose of an aircraft in which all the controls are electrically connected to a computer unit and to an instructor's control desk. The flight instruments, engine indicators and devices simulating engine noise and other flight conditions are controlled via the computer. Aircrews can gain experience of the aircraft controls with fewer flying hours and under simulated fault conditions which could not be deliberately contrived in the air.

621.38.001.8 : 545.81 **2248**

**Electronic Colorimetry.**—D. W. Thomasson. (*Electronic Engng,* March 1951, Vol. 23, No. 277, pp. 91–93.) Photocell methods of colour measurement are outlined. A new type of photocell with Ag-O-Cs and Sb-Cs layers deposited on opposite sides of an internal partition may solve the problem of obtaining constant sensitivity over the visual wavelength range.

621.38.001.8 : 623.8 **2249**

**Electronics in Naval Architecture: Some Applications to Research Problems.**—(*Engineer, Lond.,* 2nd March 1951, Vol. 191, No. 4962, p. 295.) Long summary of a paper read before the North-East Coast Institution of Engineers and Shipbuilders by L. C. Burrill and A. G. Boggis, January 1951. Replacement of mechanical by electrical devices is considered. Problems mentioned include measurement of (*a*) resonance vibrations of ships' hulls, (*b*) moment of inertia of swinging propeller, (*c*) small thicknesses, and (*d*) metacentric height.

621.383.001.8 : 535.61-15 : 778.37 **2250**

**Use of Image-Converter Tube for High-Speed Shutter Action.**—A. W. Hogan. (*Proc. Inst. Radio Engrs,* March 1951, Vol. 39, No. 3, pp. 268–270.) "The equipment described provides a means for obtaining high-speed photographs while utilizing a continuous light source. The device may be pulsed once for 'one-shot' exposures or repetitively for motion pictures or stroboscope applications. The heart of the equipment is an image-converter tube such as the 1P25. Images are impressed on the photocathode and the tube is pulsed electrically for a duration equal to the exposure time desired. The image will then appear on the fluorescent screen and may be viewed directly or photographed."

621.384 : 539.185 **2251**

**A 200-kV Neutron Generator: Part 1.**—G. Carlson. (*Ark. Fys.,* 28th Dec. 1950, Vol. 2, Part 4, pp. 277–287.) Description of apparatus constructed at the Institute of Physics at Uppsala.

621.384 : 539.185 **2252**

**A 200-kV Neutron Generator: Part 2.**—I. Bartholdson & G. Carlson. (*Ark. Fys.,* 28th Dec. 1950, Vol. 2, Part 4, pp. 289–293.) The adjustment of the generator and some preliminary measurements are described. Part 1: 2251 above.

621.384.611.2† **2253**

**Synchro-Cyclotron for Liverpool University.**—(*Engineer, Lond.,* 30th March 1951, Vol. 191, No. 4966, p. 425.) Brief note of model under construction, designed to accelerate protons to about 400 MeV.

621.384.612.1† **2254**

**Design of Acceleration Chamber and Dees for the 225-cm Cyclotron at the Nobel Institute for Physics, Stockholm.**—H. Atterling. (*Ark. Fys.,* 20th Feb. 1951, Vol. 2, Part 6, pp. 559–570.)

621.384.612.2† : 621.396.615 **2255**

**Pulser for Cyclotron Oscillator.**—W. H. Henry & J. D. Keys. (*Canad. J. Phys.*, March 1951, Vol. 29, No. 2, pp. 137–141.) The pulser for the r.f. oscillator of the McGill synchrocyclotron is described.

621.385.833 **2256**

**Approximation to Rotationally Symmetrical Potential Fields with Cylindrical Equipotential Surfaces by means of an Analytical Function.**—F. Lenz. (*Ann. Phys., Lpz.*, 10th Nov. 1950, Vol. 8, Nos. 3/4, pp. 124–128.) An analytical expression is derived for the exponentially decreasing field at a great distance from the centre of a lens with cylindrical equipotentials. For magnetic lenses, the formula gives the field as a function of the pole-piece dimensions. The closeness of the approximation is assessed by comparing the analytical results with the field distribution calculated numerically.

621.385.833 **2257**

**Second Session of the German Electron-Microscopy Society, 14th–16th April 1950.**—(*Optik*, Oct./Dec. 1950, Vol. 7, Nos. 4/6, pp. 185–335.) The text is given of some 40 papers presented at the meeting, covering electron-optical aspects and applications of electron microscopes.

621.387.4† **2258**

**Symposium of Papers on Radiation Monitoring Apparatus.**—(*Proc. Instn elect. Engrs*, Part II, April 1951, Vol. 98, No. 62, pp. 173–255.) Full text of and discussion on the following papers:—

- Nuclear Particle and Radiation Detectors: Part 1—Ion Chambers and Ion-Chamber Instruments.—D. Taylor & J. Sharpe.
- A Counting-Rate Meter of High Accuracy.—E. H. Cooke-Yarborough & E. W. Pulsford.
- An Accurate Logarithmic Counting-Rate Meter covering a Wide Range.—E. H. Cooke-Yarborough & E. W. Pulsford.
- Nuclear Particle and Radiation Detectors: Part 2—Counters and Counting Systems.—J. Sharpe & D. Taylor.
- The Development of End-Window Geiger-Müller Counter Tubes.—R. O. Jenkins.
- A Survey Equipment using Low-Voltage Halogen-Quenched Geiger-Müller Counters.—E. Franklin & W. R. Loosemore.
- Scintillation Counting Equipments.—R. B. Owen & E. A. Sayle.

621.387.4† **2259**

**Improved $CO_2$-Filled Geiger-Müller Counters.** — J. Labeyrie. (*J. Phys. Radium*, Feb. 1951, Vol. 12, No. 2, pp. 146–148.)

621.387.424† **2260**

**Time Delays in Low-Voltage Halogen-Quenched Geiger-Müller Counters.**—W. R. Loosemore & J. Sharpe. (*Nature, Lond.*, 14th April 1951, Vol. 167, No. 4250, pp. 600–601.) An interim note on an investigation in progress at Harwell.

777.2 : 621.383 **2261**

**Half-Tone Cuts produced Electronically.** — G. Washington, Jr. (*Proc. Radio Cl. Amer.*, 1951, Vol. 28, No. 1, pp. 3–10.) Illustrated description of a method of producing half-tone blocks on plastic-sheet material. The picture is scanned by a photocell, the current in which is used to control the amplitude of vibration of a red-hot stylus which jabs into the plastic sheet 350 times per second. After washing, the plate is ready for direct printing. The time required for making a 5 in. × 7 in. block is about 12 minutes.

621.385.38 **2262**

**The Industrial Applications of Gasfilled Triodes (Thyratrons).** [Book Review]—Walker. (See 2306.)

## PROPAGATION OF WAVES

621.396.11 **2263**

**1951 I.R.E. National Convention Program.**—(*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 292–315.) Summaries are given of the following papers:

48. Selective Fading of Microwaves.—A. B. Crawford & W. C. Jakes, Jr.
49. Propagation Studies at Microwave Frequencies by means of Very Short Pulses.—O. E. DeLange.
50. Low-Frequency Ionosphere Soundings with Atmospherics.—W. J. Kessler & W. F. Zetrouer, II.
51. The Effect on Propagation of an Elevated Atmospheric Layer of Nonstandard Refractive Index.—L. H. Doherty.

621.396.11 : 551.510.535 : 523.3 **2264**

**Moon Echoes and Transmission through the Ionosphere.**—F. J. Kerr & C. A. Shain. (*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 230–242.) Moon echoes of pulses with frequencies about 20 Mc/s were studied, mainly to obtain information on ionospheric transmission of radio signals at small angles of elevation. Special transmissions of single pulses or groups of pulses were made from the h.f. broadcasting station at Shepparton, Victoria, Australia, and receivers were used at two distant stations in Australia and three in America. Preliminary results have been reported previously [2030 of 1949 (Kerr et al.)]. The observations extended over about a year; echoes were received in 24 out of 30 experiments. Comparison of the results with those to be expected from orthodox ray theory for a horizontally stratified ionosphere indicates that (*a*) observed echo intensities were well below the theoretical values, (*b*) minimum moon altitudes at which echoes were first detected were unexpectedly large. The close correlation of these anomalies with $f_0F_2$ values suggests that they may be explained by irregularities in the $F_2$ region. Another possible explanation of the discrepancies is inadequacy of the ray theory for very oblique incidence. Discussion of the two types of fading observed with moon echoes shows that for the frequencies used the moon is a 'rough' reflector.

## RECEPTION

621.396.621 **2265**

**1951 I.R.E. National Convention Program.**—(*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 292–315.) Summaries are given of the following papers:

2. Cross-Correlation and the Optimum Signal-to-Noise Ratio for Periodic Systems.—M. Leifer & N. Marchand.
3. Detection of Repetitive Signals in Noise by Correlation.—Y. W. Lee & L. G. Kraft.
31. Echo Distortion in the F.M. Transmission of Frequency-Division Multiplex.—W. J. Albersheim & J. P. Schafer.
128. Semi-Automatic Fabrication of Audio and Video Equipment.—W. H. Hannahs, R. Bahr, Jr, & J. Caffiaux.
131. Radio Receiver Subminiaturization Techniques.—G. Shapiro.
170. A Practical Speech Silencer for Radio Receivers.—R. C. Jones.
176. Internal Television Receiver Interference.—B. Amos & W. Heiser.

621.396.621 **2266**

**The LD-R1 Single Sideband Radio Receiver.**—G. Rodwin. (*Bell Lab. Rec.*, April 1951, Vol. 29, No. 4, pp. 169–172.) A single-sideband receiver for radiotelephony in the frequency range 4–23 Mc/s. Up to four speech channels can be provided with one carrier. A double superheterodyne circuit is used, with optional crystal or variable-frequency first oscillator. The frequency of the second oscillator is automatically controlled to synchronize the second i.f. output with a locally generated demodulating frequency.

621.396.621 : 621.396.812.3 **2267**

**Experimental Evaluation of Diversity Receiving Systems.**—J. L. Glaser & S. H. Van Wambeck. (*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 252–255.) Apparatus is described which records the total times during which the signal from a diversity receiving system lies within each of seven signal-strength ranges. The use of the data so obtained for comparison of the statistical properties of different systems is discussed.

621.396.621 : 621.396.812.3 **2268**

**Performance of Diversity Receiving Systems.**—S. H. Van Wambeck & A. H. Ross. (*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 256–264.) Results are reported of investigations carried out continuously over a period of two years on various systems using frequencies in the range 7–16 Mc/s over a 900-mile path. Improvement in reception provided by the systems is shown graphically, and the variability in improvement is indicated. A diversity system using three spaced aerials is found to be definitely superior to one using only two aerials which, in turn, is generally more effective than a polarization-diversity system.

## STATIONS AND COMMUNICATION SYSTEMS

621.3.018.42(083.71) **2269**

**A Proposed Numbered Frequency Band Subdivision Plan.**—C. W. Young. (*TV Engng, N.Y.*, March 1951, Vol. 2, No. 3, pp. 24–25, 30.) A scheme is proposed whereby small portions of a band could be referred to simply and clearly.

621.39 **2270**

**1951 I.R.E. National Convention Program.**—(*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 292–315.) Summaries are given of the following papers:

1. A Storage Tube as an Amplitude Distribution Analyzer.—R. E. Nienburg & T. F. Rogers.
2. Cross-Correlation and the Optimum Signal-to-Noise Ratio for Periodic Systems.—M. Leifer & N. Marchand.
3. Detection of Repetitive Signals in Noise by Correlation.—Y. W. Lee & L. G. Kraft.
4. Error Reduction in the Determination of Electronic System Parameters.—L. S. Schwartz.
5. Coding Processes for Bandwidth Reduction in Picture Transmission.—A. E. Laemmel.
22. The Generation of Single-Sideband Suppressed-Carrier Signals by a New Balancing Method.—H. M. Swarm.
28. A.M.-F.M. Analogy.—H. C. Harris.
29. Survey of Electronic Commutation Methods.—R. S. Butts.
30. High-Frequency Radio Communication System utilizing Phase-Modulation Transmission and Single-Sideband Reception.—H. F. Meyer & H. Y. Littlefield.
31. Echo Distortion in the F.M. Transmission of Frequency-Division Multiplex.—W. J. Albersheim & J. P. Schafer.
52. Master Control Facilities for a Large Studio Center.—R. H. Tanner.
54. Performance of Sectionalized Broadcasting Towers.—C. E. Smith.
71. Generation of Sidebands due to Gain and Phase Shift Modulations in a Traveling Wave Tube Amplifier.—M. Arditi, A. G. Clavier & P. Parzen.
108. Aircraft and Airport Characteristics.—L. P. Tabor.
109. Economic Demand.—F. B. Lee.
110. Human Engineering.—P. M. Fitts.
111. Traffic Control Theory.—D. H. Ewing.

621.39.001.11 **2271**

**Adaptation of Message to Transmission Line: Part 1 — Quanta of Information.**—B. Mandelbrot. (*C. R. Acad. Sci., Paris*, 30th April 1951, Vol. 232, No. 18, pp. 1638–1640.) Since words, in the ordinary sense, satisfy a privileged statistical system of the form $p_n \sim A\ (n + n_0)^{-B}$, they constitute natural quanta of information. The transmission of the message is considered from the standpoint of 'cost' (a term related to entropy) and of structure.

621.39.001.11 **2272**

**Information and Regression.** — R. Féron & C. Fourgeaud. (*C. R. Acad. Sci., Paris*, 30th April 1951, Vol. 232, No. 18, pp. 1636–1638.) Quantity of information is investigated by probability-calculus methods.

621.39.001.11 **2273**

**Definition of Information.**—E. Reich. (*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, p. 290.) The uniqueness of the definition of the rate $R$ of information transfer is examined, since it is conceivable that a different definition of information might lead to different criteria for communication-link design. The basic postulate here proposed for $R$ to satisfy is that $R$ is invariant under any transformation of $x$ and $y$ that merely amounts to a relabelling of the message symbols. If $R$ is given by the formula proposed by Shannon (1361 and 1649 of 1949), the postulate is satisfied. An expression representing a certain class of possible definitions is considered which involves (*a*) the conditional probability that $x$ was transmitted if $y$ was received, and (*b*) a function $F\ (u, v)$ of two real variables to be chosen in such a way that the fundamental postulate is satisfied. With the usual continuity assumption, the only possible choice for the function $F$ leads to Shannon's expression for $R$. Details of the derivation are to be published in a mathematical journal.

621.39.001.11 : 621.396.933.4 **2274**

**Application of the Information Theory to System Design.**—W. G. Tuller. (*Elect. Engng, N.Y.*, Feb. 1951, Vol. 70, No. 2, pp. 124–126.) An assessment of the facilities required to transmit certain standard messages from a traffic control centre to aircraft. Any surplus channel capacity can be used for checking messages and for improving operation at low signal/noise ratios.

621.391.32 **2275**

**Subterranean Communication by Electric Waves.**—H. P. Williams. (*J. Brit. Instn Radio Engrs*, March 1951, Vol. 11, No. 3, pp. 101–111.) Communication through ground over distances of several hundred yards is possible using frequencies of the order of 1 kc/s. The electrostatic field must be used; various electrode systems for setting up such a field are described and analysed. Electrode spacings of the order of a mile may be desirable. The terminal equipment can be made compact and easily portable.

621.396 : 628.1/.2 **2276**

**Electronics in a Large Public Utility — The Sydney Metropolitan Water, Sewerage and Drainage Board.**—H. A. Stowe. (*Proc. Instn Radio Engrs, Aust.*, March 1951, Vol. 12, No. 3, pp. 69–76.) The development of the use of radio communications by the Sydney Water Board is outlined, and systems in actual use are described, including cableway signalling, flood warning and shaft-cage signalling.

621.396.44 + 621.397.24 **2277**

**Television and Sound by Wire.**—R. I. Kinross. (*Wireless World*, April 1951, Vol. 57, No. 4, pp. 126–129.) Describes a system being installed in Montreal for the simultaneous distribution of sound and television programmes by wire. Two television and eight sound programmes modulate separate carriers, the vision carrier frequencies being 16 Mc/s and 28 Mc/s and the sound carriers 180–320 kc/s at 20-kc/s spacing. Trunk coaxial feeders, with repeaters at one-mile intervals, are used to feed subscriber cables, the total area covered having a radius of about 5 miles.

621.396.6 **2278**

**Equipment for 450 Mc/s.**—L. P. Morris. (*FM-TV*, March 1951, Vol. 11, No. 3, pp. 26–28.) Equipment is described for adapting standard 152-Mc/s communication transmitters and receivers for operation in the new 450–460-Mc/s band. The conversion is performed by frequency tripling at the transmitter and heterodyning at the receiver.

621.396.931 **2279**

**Operational Study of a Highway Mobile Telephone System.**—L. A. Dorff. (*Elect. Engng, N.Y.*, March 1951, Vol. 70, No. 3, pp. 236–241.) Paper presented at the 1951 A.I.E.E. Winter General Meeting, New York. The United States system for communication between telephone subscribers and vehicles on the highways operates in the 30–44-Mc/s band; the country is divided into seven zones and each zone is allocated one frequency in this band for base stations and one for all vehicles. Each zone is divided into overlapping areas containing a base transmitter and receivers. An account is given of trials to devise operating procedure to minimize the effect of interference between areas and increase the traffic-handling capacity of the system.

621.396.97 : 621.396.66 **2280**

**Automatic Program Monitor.**—J. Moir. (*FM-TV*, March 1951, Vol. 11, No. 3, pp. 42–45.) See 1491 of June (Rantzen, Peachey & Gunn-Russell).

621.396.97 : 621.396/.397].8 **2281**

**The Variation with Frequency of the Signal Range of F.M. and Television Broadcasting Stations.**—K. A. Norton & E. W. Allen. (*J. Brit. Instn Radio Engrs*, March 1951, Vol. 11, No. 3, pp. 93–100.) The factors limiting the range of broadcast transmissions in the v.h.f. and u.h.f. bands are discussed, and the two main types of noise, viz. receiver noise and cosmic noise, are discussed. Curves are given showing the effective range of a transmitter when various types of receiver aerial are used. Above 100 Mc/s range is limited by receiver noise, which in present receivers is much greater than the theoretically attainable minimum.

621.396.97 + 621.397] (410) **2282**

**Sound and Vision Broadcasting in Great Britain.**—(*Nature, Lond.*, 21st April 1951, Vol. 167, No. 4251, pp. 617–619.) Summary of the Report of the Broadcasting Committee, 1949, published by H.M. Stationery Office, 1951, at 6s. 6d.

621.396 **2283**

**Drahtloser Überseeverkehr (Radio Oversea Communication).** [Book Review]—P. Kotowski & H. Sobotka. Publishers: S. Hirzel, Leipzig, 2nd edn 1950, 271 pp., DM 14.80. (*Elektrotechnik, Berlin*, March 1951, Vol. 5, No. 3, p. 141.) Strongly recommended to a wide circle of readers.

## SUBSIDIARY APPARATUS

621-526 + 621.396.68 **2284**

**1951 I.R.E. National Convention Program.**—(*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 292–315.) Summaries are given of the following papers:

62. Network Synthesis applied to Feedback Control. —J. G. Truxal.
65. Electrical-Mechanical Equivalent Network Synthesis.—A. A. Gerlach.
130. Power Supplies for Television Receivers.—A. M. Levine & S. Moskowitz.

621-526 **2285**

**Transducers — Sensing Elements for Servos.**—J. R. Stovall. (*Elect. Mfg, N.Y.*, April 1950, Vol. 45, No. 4, pp. 88–92 . . 184.) Seventeen types of sensing elements are enumerated for converting position, motion or pressure into electrical signals for servo operation. Some practical applications for measurement, recording and control are described.

621.319.45.025 : 621.314.64 **2286**

**Variation with Frequency of the Dynamic Characteristic $i(V)$ of the System Al-Al$_2$O$_3$-Electrolyte.**—W. C. van Geel & B. C. Bouma. (*Philips Res. Rep.*, Dec. 1950, Vol. 5, No. 6, pp. 461–475.) A tentative explanation is advanced of the phenomena described in 1254 of May (Dekker & van Geel). It is assumed that the oxide layer contains an excess of Al in the vicinity of the Al layer; in this region it is an excess semiconductor. The other part of the oxide layer is the barrier, whose thickness changes with the direction of the applied voltage, giving rise to the loop observed in the characteristic. The variation of thickness is due to electrolysis in the $Al_2O_3$ layer. A possible alternative assumption is that the oxide layer in the vicinity of the electrolyte contains a surplus of oxygen, corresponding to a defect semiconductor.

621.352 **2287**

**Some Notes on Unsaturated Standard Cells.**—F. C. Holmes. (*N.Z. elect. J.*, 25th April 1950, Vol. 23, No. 4, pp. 300–301.) Errors up to 0·5% may be introduced when Weston standard cells are used without suitable precautions. The causes include unequal heating of the two limbs of the cell, hysteresis or temporary changes of e.m.f. resulting from abrupt changes of cell temperature, and decrease in e.m.f. with age of the cell.

## TELEVISION AND PHOTOTELEGRAPHY

621.396/.397].8 : 621.396.97 **2288**

**The Variation with Frequency of the Signal Range of F.M. and Television Broadcasting Stations.**—Norton & Allen. (See 2281.)

621.396.97 + 621.397](410) **2289**

**Sound and Vision Broadcasting in Great Britain.**—(See 2282.)

621.397.24 + 621.396.44 **2290**

**Television and Sound by Wire.**—Kinross. (See 2277.)

621.397.24 **2291**

**Local Wire Television Networks.**—C. N. Nebel. (*Elect. Engng, N.Y.*, Feb. 1951, Vol. 70, No. 2, pp. 130–135.) Description, with circuit and performance details, of terminal, repeater and equalizer equipment developed for local video distribution, existing telephone facilities being used where practicable. A flat response with minimum cross-talk, noise and losses is obtained by the use of special cables and by pre-attenuation of the lower frequencies and subsequent equalization.

621.397.5 **2292**

**1951 I.R.E. National Convention Program.**—(*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 292–315.) Summaries are given of the following papers:

5. Coding Processes for Bandwidth Reduction in Picture Transmission.—A. E. Laemmel.
6. Colorimetry in Television.—F. J. Bingley.
7. Subjective Sharpness of Additive Color Pictures.—M. W. Baldwin, Jr.
8. Color Multiplexing by Sine-Wave Functions.—N. Marchand.
9. Measurement and Control of Color Characteristics of Flying Spot Color Signal Generator.—R. Moore, J. Fisher & J. Chatten.
10. Performance of Carrier Synchronizing Circuits for Color Television Receivers.—E. M. Creamer, Jr, & M. I. Burgett.
11. A Simple Pattern Generator for Color Television Signals.—R. P. Burr, W. R. Stone & R. O. Noyer.
55. Increased Economy and Operating Efficiency of Television Broadcast Stations through Systemic Design.—R. A. Isberg.
56. Technical Considerations of Television Recording.—G. E. Hamilton.
68. The Design of 90°-Deflection Picture Tubes.—H. Grossbohlin.
127. Wide-Angle Deflection Yoke Design.—H. Thomas.
128. Semi-Automatic Fabrication of Audio and Video Equipment.—W. H. Hannahs, R. Bahr, Jr, & J. Caffiaux.
129. U.H.F. Converter.—B. F. Tyson.
148. Parallel Operation of Vacuum Tubes at U.H.F. to obtain High Transmitter Power.—W. H. Sayer, Jr, & E. Mehrbach.
149. An Ultra Portable Television Pickup Equipment.—L. E. Flory, W. S. Pike, J. E. Dilley & J. M. Morgan.
150. The Technique of Dot Arresting for Television Transmission using Dot Interlace.—K. Schlesinger.
151. A Sweep Frequency Method for Measuring the Transmission-Amplitude Characteristic of a Television Transmitter.—J. Ruston.
175. Synchroflection: a Horizontal Deflection System possessing Inherent Noise Immunity.—W. K. Squires & K. R. Wendt.
176. Internal Television Receiver Interference.—B. Amos & W. Heiser.
177. An R.F. Amplifier for the U.H.F. Television Band.—B. F. Tyson & J. G. Weissman.
178. Television Line Selector with Automatic Identifier.—J. Fisher.
179. Development of a High Stability U.H.F. Television Tuner.—M. W. Slate, J. P. Van Duyne & E. G. Mannerberg.

621.397.5 **2293**

**Image Gradation, Graininess and Sharpness in Television and Motion Picture Systems: Part 1—Image Structure and Transfer Characteristics.**—O. H. Schade. (*J. Soc. Mot. Pict. Televis. Engrs*, Feb. 1951, Vol. 56, No. 2, pp. 137–177.) The physical quality of motion-picture and television images is determined by the transfer characteristic, the signal/noise ratio and the resolution. A detailed analysis is given of the transfer characteristics of television camera tubes and motion-picture film. Means are described for improving the fidelity of reproduction; practical examples are given in illustration. The signal/noise ratio and resolution will be discussed in parts 2 and 3.

621.397.6 **2294**

**The Genlock — A New Tool for Better TV Programming.**—J. H. Roe. (*J. Soc. Mot. Pict. Televis. Engrs*, Feb. 1951, Vol. 56, No. 2, pp. 232–234.) Long abstract of paper published in full in *Proc. Nat. Electronics Conference, Chicago*, 1950, Vol. 6, pp. 178–184. The unit described enables a local synchronizing-pulse generator to be locked in phase with a distant one. This makes possible the use of 'lap-dissolves' and superpositions involving pictures from two distinct programme sources.

621.397.62 **2295**

**Matching of the Frame Output Stage to the Deflection Coils in Television Receivers: Part 2—High Impedance Deflection Coils.**—P. D. van der Knaap & J. Jager. (*Philips tech. Commun., Aust.*, 1951, No. 1, pp. 9–13.) Design requirements are analysed. In the case of high-impedance deflection coils, a choke is used in the anode circuit of the output valve, with the deflection coils connected in parallel through a coupling capacitor. A comparison is made with the low-impedance case using a transformer, discussed in part 1 (1793 of July).

621.397.621.2 **2296**

**Television Image Reproduction by use of Velocity-Modulation Principles.**—M. A. Honnell & M. D. Prince. (*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 265–268.) The video signal (obtained in the usual manner) is not applied to the grid of the viewing tube but is superimposed on the horizontal-deflection voltage. The resulting brightness is proportional to the derivative of the signal. The system may have some application in the reproduction of printed material and line drawings and for radar. The resolution of an ordinary television picture may be improved by the use of a suitable amount of velocity modulation combined with grid modulation.

621.397.7 : 534.861.1 **2297**

**Television Studio Acoustics.**—M. Rettinger. (*Audio Engng*, April 1951, Vol. 35, No. 4, pp. 13–14 . . 47.) Discussion of methods of acoustic treatment of television studios to ensure optimum sound quality.

## TRANSMISSION

621.396.61 **2298**

**1951 I.R.E. National Convention Program.**—(*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 292–315.) Summaries are given of the following papers:

24. Stabilized Variable-Frequency Transmitter Exciter for Military H.F. Equipment.—J. Bush.
26. Crystal Control of a 4-kW, 1 036-Mc/s Transmitter.—J. W. Clark, R. W. Kane, W. G. Abraham, N. P. Hiestand & S. F. Varian.
148. Parallel Operation of Vacuum Tubes at U.H.F. to obtain High Transmitter Power.—W. H. Sayer, Jr, & E. Mehrbach.
190. Low-Distortion Frequency-Modulation Modulators.—A. R. Vallarino & C. Greenwald.

621.396.61 **2299**

**Air-Cooled Variometer for Mobile S.W. Transmitter.**—W. Schirp. (*Elektrotech. Z.*, 15th March 1951, Vol. 72, No. 6, pp. 171–173.) Constructional details are given for the output-stage variometer of a 20-kW mobile transmitter, particular attention being paid to the air-cooling and roller-contact arrangements. The wavelength range is 12.5–100 m. Only the windings in circuit at the highest frequencies need to be cooled.

621.396.61 : 621.396.933 **2300**

**Design of a Loran Transmitter.**—R. H. Myers. (*Elect. Commun.*, March 1951, Vol. 28, No. 1, pp. 31–45.) Problems encountered in the design of a new type of transmitter are discussed and the equipment described. The main objectives were (*a*) to narrow the radiated frequency spectrum, (*b*) to increase the peak output to 1 MW, and (*c*) to fix the phase of the carrier with respect to the pulse envelope in order to enable cycle-matching technique to be used. Theoretical considerations showed that a cosine-squared shape of pulse was suitable. Pulse shaping was achieved by grid modulation in the penultimate stage. By deriving the modulation voltage from the master oscillator used for generating the r.f. driving voltage, phase locking between the two was obtained.

## VALVES AND THERMIONICS

537.581 : 539.16 **2301**

**Effect of Radioactivity on the Thermoelectronic Emission from Cathodes.**—J. Debiesse, G. Neyret, J. Challansonnet & J. Amoignon. (*C. R. Acad. Sci., Paris*, 28th May 1951, Vol. 232, No. 22, pp. 2015–2016.) When a cathode emits $\beta$ or $\gamma$ radiations [see 1522 of June (Debiesse, Challansonnet & Neyret)] a strong disturbance of the e.s. field at the emission centres is produced. The effect of these disturbances on the thermoelectronic emission was studied, using cathode bases of Ni with 5% Co, coated with Ba/Sr carbonates. Lower currents were observed from the radioactive cathodes than from similar, but inert, cathodes. Working from a simplified form of a known empirical formula for saturation current, the work function is found to be 1·5–2 V for the radioactive cathodes and of the order of 1 V for the inert cathodes. Further experiments were made with pure W cathodes, the radioactive specimens again giving lower emission currents.

621.314.632 + 621.383] : 546.289 **2302**

***p-n* Junction Rectifier and Photo-Cell.**—W. J. Pietenpol. (*Phys. Rev.*, 1st April 1951, Vol. 82, No. 1, pp. 120–121.) Description of two devices made from *p–n* junctions in single-crystal Ge by the process described by Teal, Sparks & Buehler (1682 of July). The first of these is a rectifier which retains its high impedance in the reverse direction to well above 1 000 V, where its value is 117 MΩ. In the forward direction the d.c. resistance at 1 V is 237 Ω. The saturation current increases by a factor of about 10 for a temperature increase from 25° to 60°C. The rectifier can be used slightly above the a.f. range. The second device is a photocell which responds to light of wavelength up to 1.9μ with a quantum efficiency of unity. The sensitivity to a light source of 2 900°K colour temperature is about 0.01 mA/millilumen. The dark impedance is of the order of megohms.

621.383.42 **2303**

**The Electron Voltaic Effect.**—W. Ehrenberg, Chi-Shi Lang & R. West. (*Proc. phys. Soc.*, 1st April 1951, Vol. 64, No. 376A, p. 424.) Experiments indicate that photovoltaic cells are sensitive to electron bombardment, the gain (i.e. ratio of circulating current to bombarding current) depending on the voltage of the bombarding electrons.

621.385 + 621.396.615 **2304**

**1951 I.R.E. National Convention Program.**—(*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 292–315.) Summaries are given of the following papers:

18. The Effect of Secondary Emission in Power Tubes.—Hsiung Hsu.
19. Reflex Resnatron Operation and its Implication for Bandwidth.—M. Garbuny & G. E. Sheppard.
20. The Multibeam Electron Coupler — an Improved Spiral-Beam Electron Tube for the Modulation and Control of Power at U.H.F.—C. L. Cuccia.
21. A New Single-Cavity Resonator for a Multianode Magnetron.—J. S. Needle, G. Hok, G. R. Brewer & H. W. Welch.
43. A Coaxial Power Triode for 50-kW Output up to 110 Mc/s.—R. H. Rheaume.
44. A High-Power Tetrode.—C. E. Murdock.
45. The Reflex Resnatron.—G. E. Sheppard, M. Garbuny & J. R. Hansen.
46. Transmitting Tube suitable for U.H.F. Television.—W. G. Abraham, F. L. Salisbury & S. F. Varian.
47. Frequency-Modulated High Efficiency Klystron Transmitter.—M. Chodorow & S. P. Fan.
70. A Miniature Traveling-Wave Tube for the Lower U.H.F. Band.—R. Adler.
97. The Plasmatron, a Continuously Controllable Gas Tube.—E. O. Johnson & W. M. Webster.
98. Switching Time Limitations in Hydrogen Thyratrons.—J. B. Woodford, Jr, & E. M. Williams.
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100. New Vacuum-Tube Materials.—E. B. Fehr & A. P. Haase.
121. A Five-Digit Parallel Coder Tube.—J. V. Harrington, K. N. Wulfsberg & G. R. Spencer.
192. A *K*-Band Amplifier Klystron.—W. G. Abraham, J. W. Clark, D. L. Snow & S. F. Varian.
193. Mode Interactions in Magnetron Oscillators.—R. R. Moats.

621.396.822 **2305**

**Theory of the Shot and Johnson Effects.**—H. Dänzer. (*Ann. Phys., Lpz.*, 10th Nov. 1950, Vol. 8, Nos. 3/4, pp. 176–186.) A unified mathematical treatment of the two effects is developed.

621.385.38 **2306**

**The Industrial Applications of Gasfilled Triodes (Thyratrons).** [Book Review]—R. C. Walker. Publishers: Chapman & Hall, London, 40s. (*Engineering, Lond.*, 9th March 1951, Vol. 171, No. 4441, p. 276.) A comprehensive treatment, with clear circuit diagrams and references to original papers.

621.396.615.141/.142 + 621.392.26† **2307**

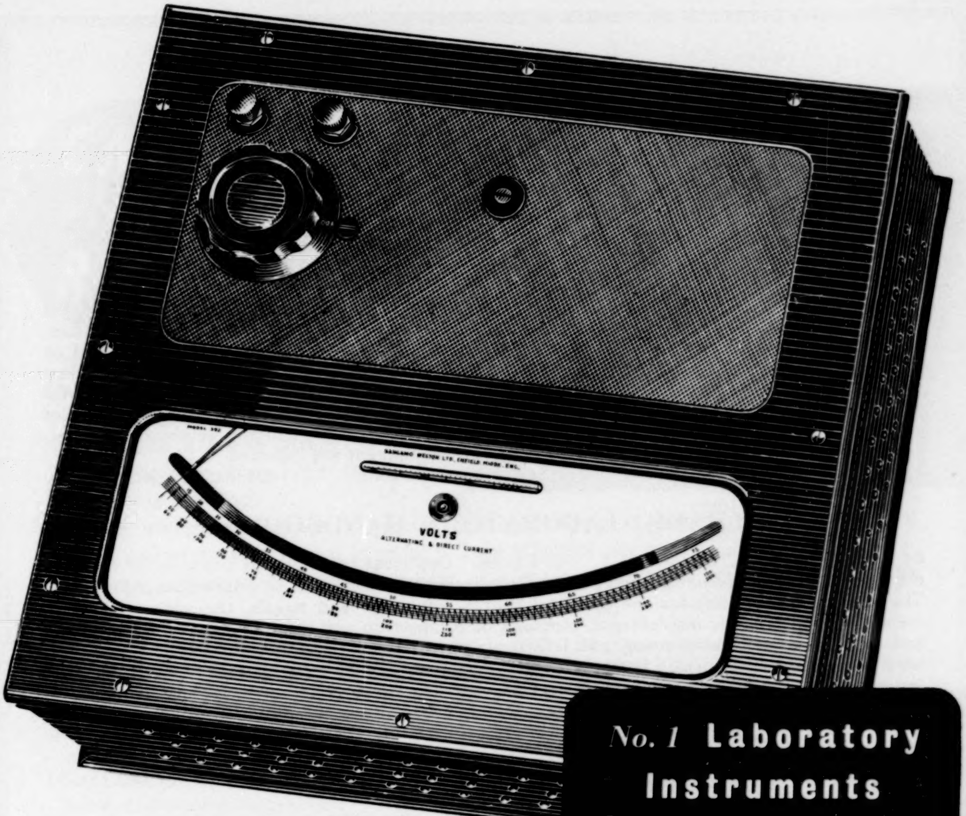
**Electromagnetic Problems of Microwave Theory.** [Book Review]—Motz. (See 2113.)

## MISCELLANEOUS

37 **2308**

**1951 I.R.E. National Convention Program.**—(*Proc. Inst. Radio Engrs*, March 1951, Vol. 39, No. 3, pp. 292–315.) Summaries are given of the following papers:

58. Educational Requirements for Development Engineers in Electronic and Communication Technology.—M. J. Kelly.
59. Making Engineering Education Professional.—B. R. Teare, Jr.
60. Using Tests to Select Engineers.—W. G. Findley.
61. Orienting the Engineer in Industry.—E. W. Butler.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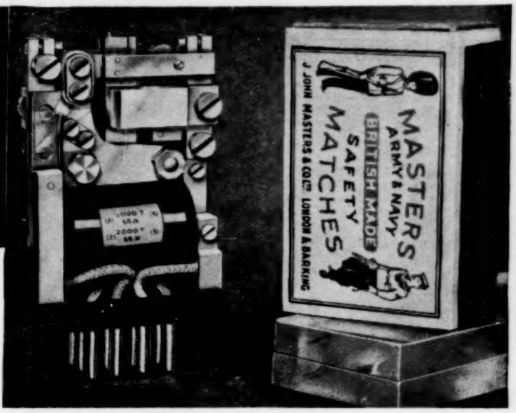

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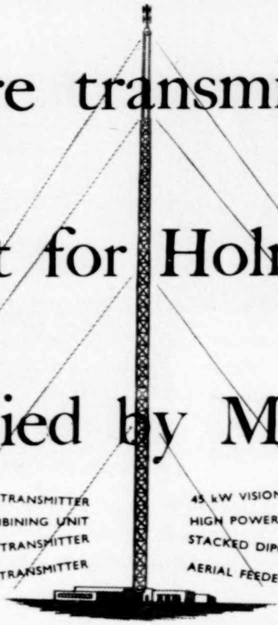

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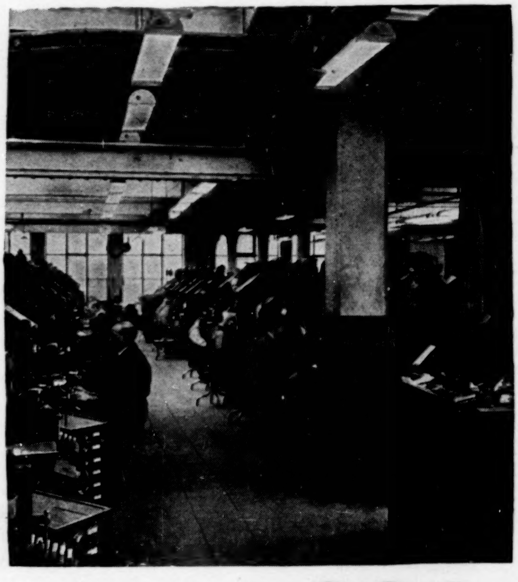

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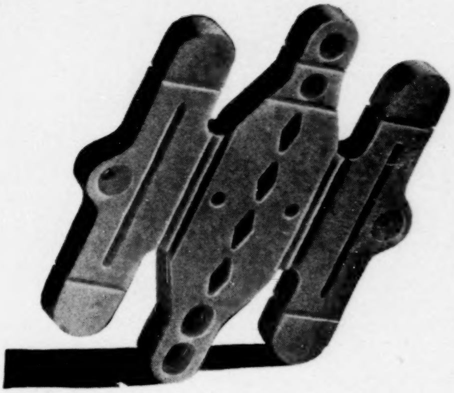

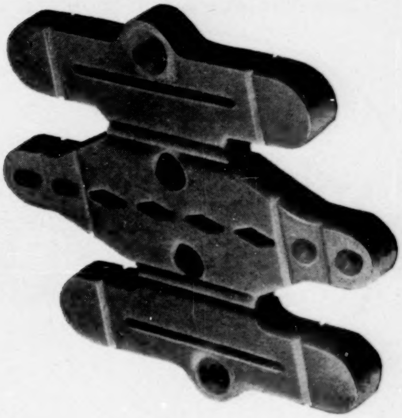

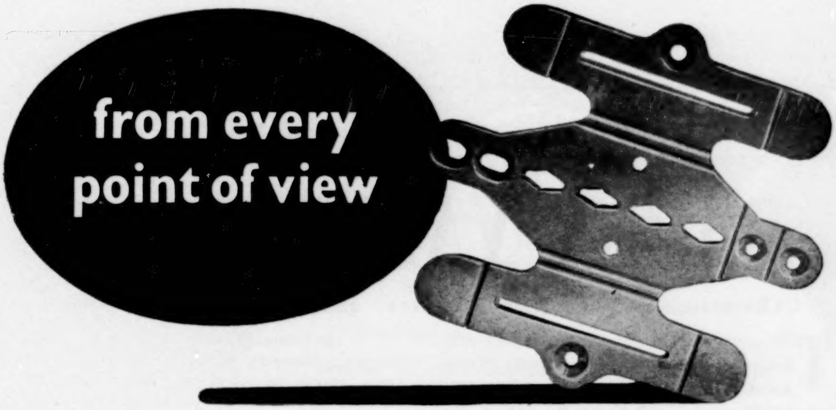

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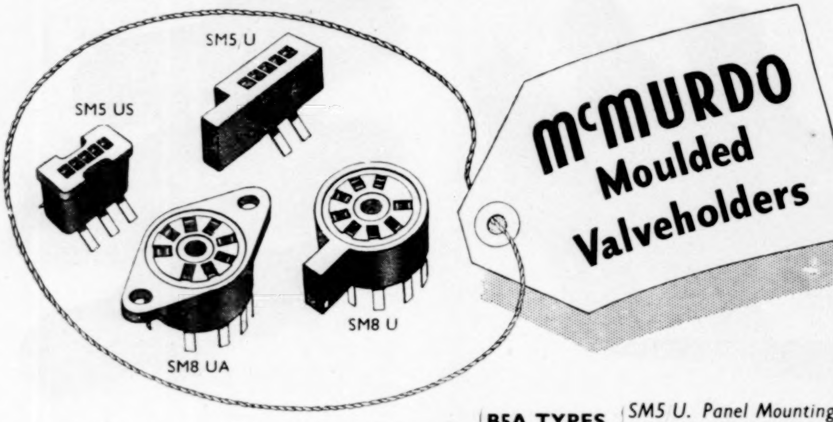

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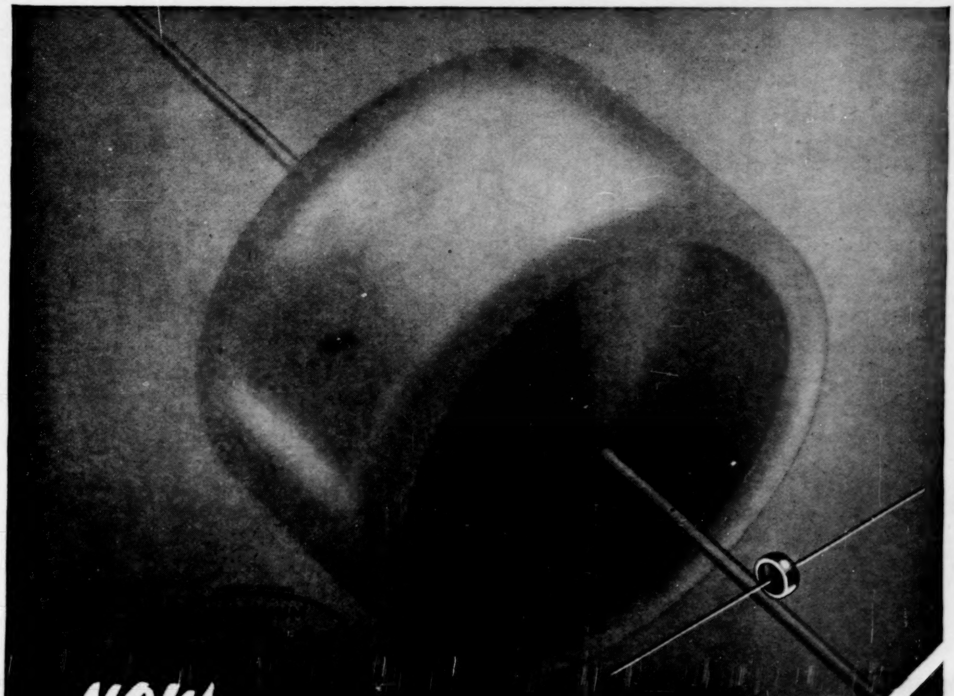

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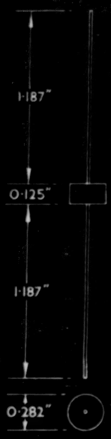

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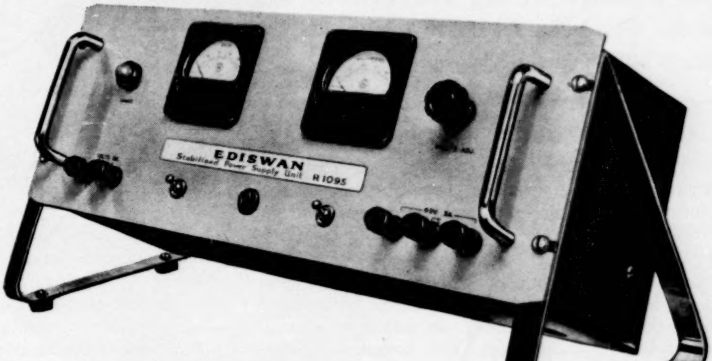

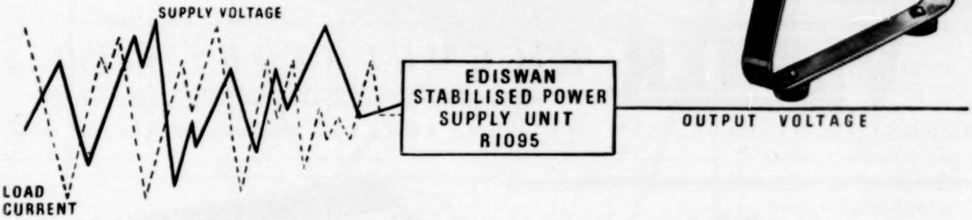

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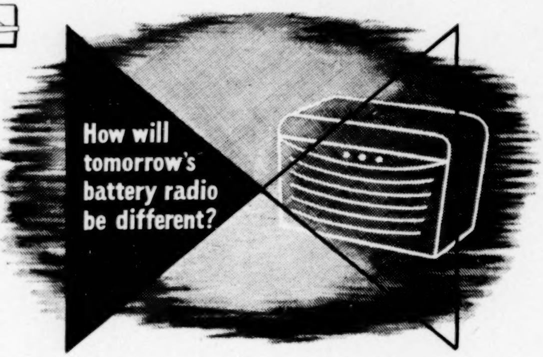

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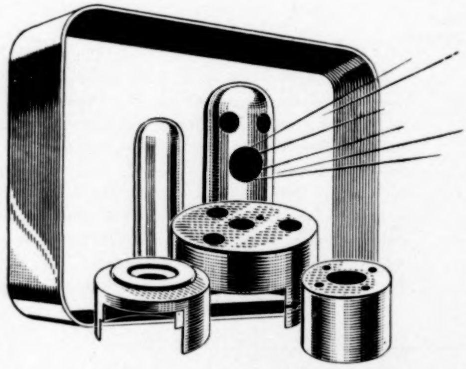

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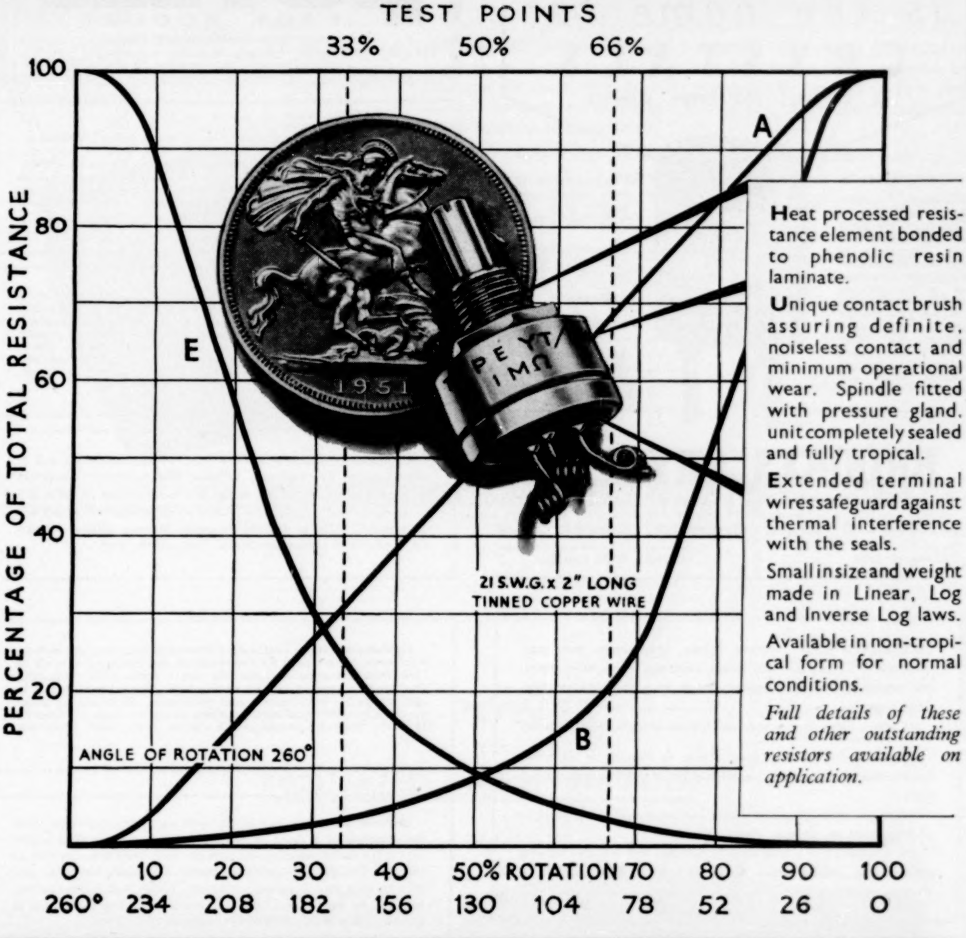

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Engineers to initiate and supervise the layout, construction and test of prototypes (to Ministry standards) of special electronic circuits for production. Considerable experience of similar work is essential and familiarity with miniature practice is desirable. Experience of radar circuits and technique would be an advantage. Senior engineers' salaries in range £800 per annum and juniors £600 per annum. Location, special laboratory in Bedfordshire. Write, giving full details and quoting ref. 907, to Central Personnel Services, English Electric Co., Ltd., 24-30 Gillingham Street, Westminster, S.W.1.

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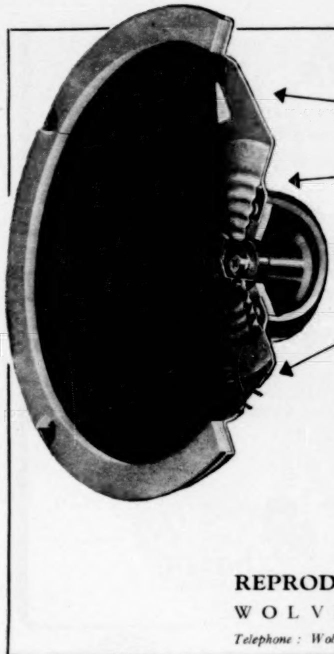

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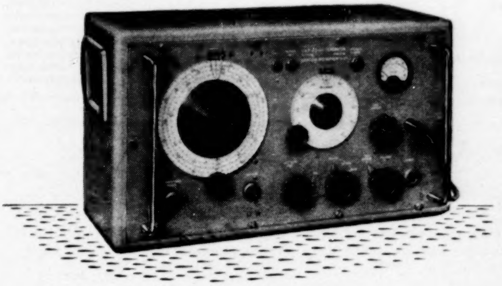

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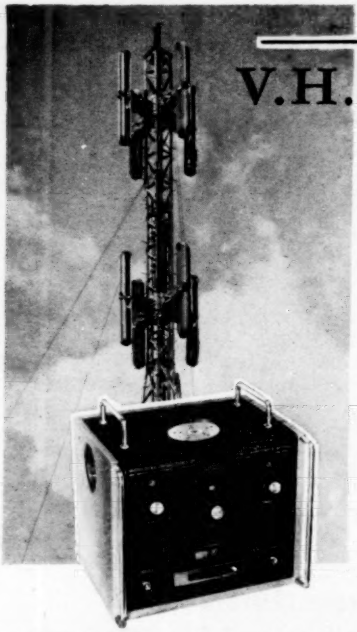

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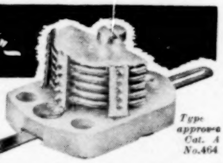

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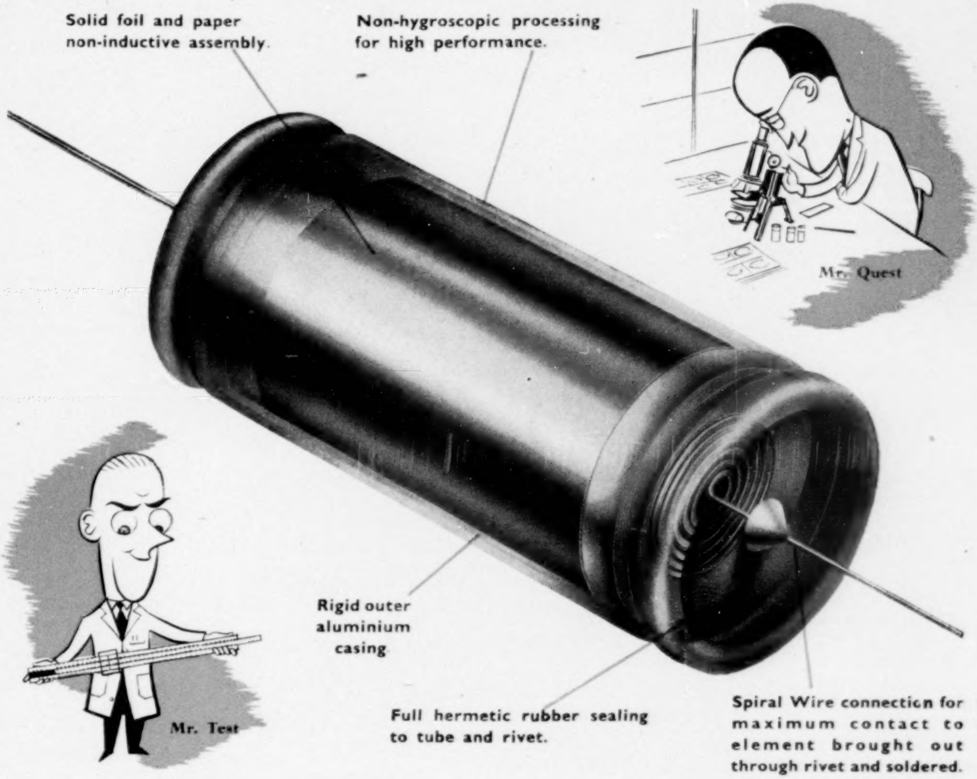
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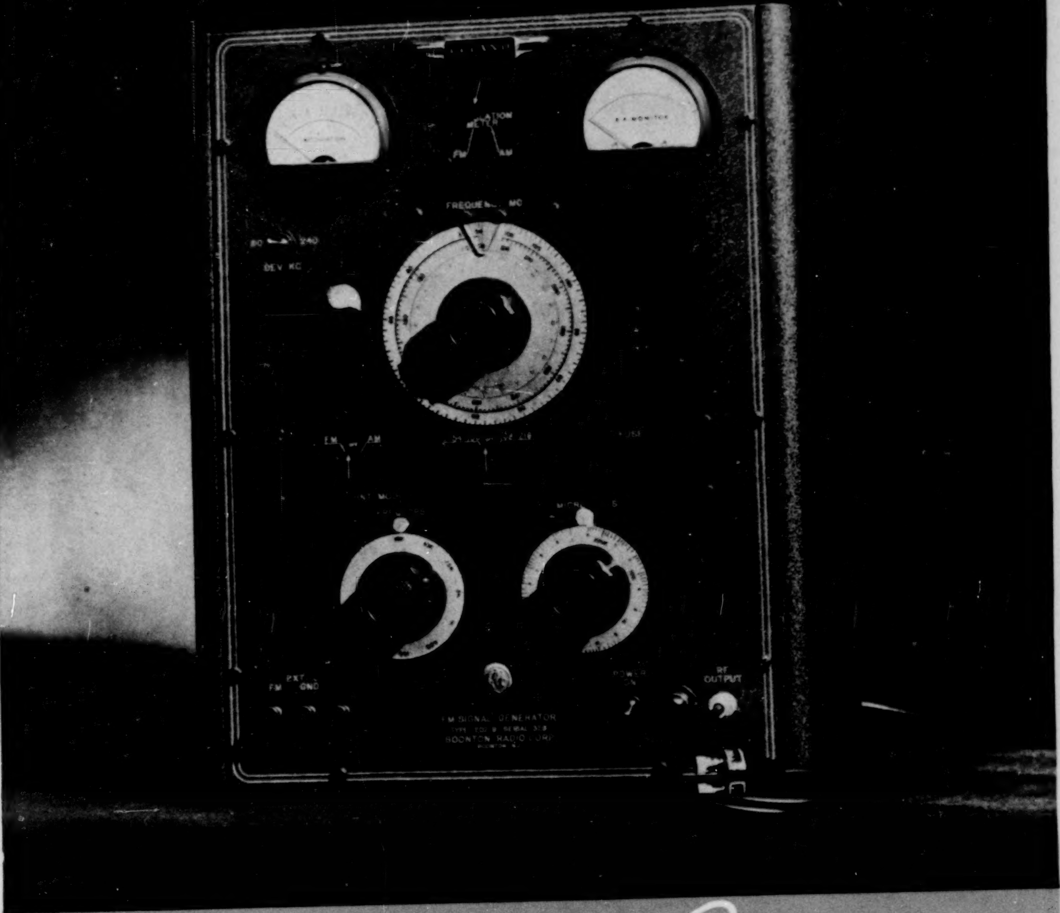

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